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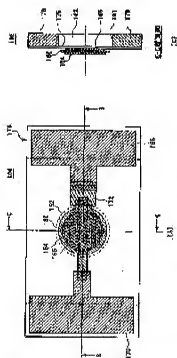
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(54) PIEZOELECTRIC DEVICE, MODULE BODY, LIQUID CONTAINER AND INK CARTRIDGE



(57)Abstract:

PROBLEM TO BE SOLVED: To accurately detect the residual amount of ink without requiring a complicated seal structure caused by the attachment of a detection electrode.

SOLUTION: A piezoelectric device is provided to a liquid container to detect the consumption state of the liquid in the liquid container and has a vibration part generating vibration by the deformation of a piezoelectric element. The vibration part has a shape symmetric with respect to the center of the vibration part.

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CLAIMS

[Claim(s)]

[Claim 1] It is the piezoelectric device characterized by equipping a liquid container, and being the piezoelectric device which detects the consumption condition of the liquid in this liquid container, for said piezoelectric device having the oscillating section which vibration generates according to deformation of a piezo electric crystal component, and this oscillating section having a symmetrical configuration to the core.

[Claim 2] The piezoelectric device according to claim 1 characterized by said oscillating section of said piezoelectric device having an almost circular configuration.

[Claim 3] The up electrode with which said piezoelectric device was formed in the top face of a piezo-electric layer and this piezo-electric layer, the lower electrode prepared in the inferior surface of tongue of said piezo-electric layer, And it is the piezoelectric device according to claim 1 or 2 which a top face touches said lower electrode, and at the bottom [a part of] is equipped with the diaphragm in contact with said liquid in said liquid container, and is characterized by said oscillating section containing some of said piezo-electric layer, said up

electrodes, said lower electrodes, and said each diaphragms [at least].

[Claim 4] The piezoelectric device according to claim 3 with which each principal piece of said piezo-electric layer, said up electrode, and said lower electrode is characterized by being said oscillating section and the configuration where a concentric circle is almost circular.

[Claim 5] Said piezoelectric device is a piezoelectric device according to claim 3 characterized by having a cavity in contact with said liquid in the location where a top face touches said inferior-surface-of-tongue side in contact with said liquid of said diaphragm, an inferior surface of tongue is further equipped with the substrate in contact with said liquid in said liquid container, and said substrate faces said oscillating section.

[Claim 6] The piezoelectric device according to claim 5 with which said cavity is characterized by said oscillating section and being the circle configuration of a concentric circle mostly.

[Claim 7] The piezoelectric device according to claim 5 with which deformation of said diaphragm by said residual vibration is characterized by being larger than deformation of said substrate.

[Claim 8] The piezoelectric device according to claim 5 with which the knot of vibration of said oscillating section is characterized by being located near the periphery section of said cavity.

[Claim 9] Said piezoelectric device is a piezoelectric device according to claim 3 with which a top face touches said inferior-surface-of-tongue side in contact with said liquid of said diaphragm, it has further the attachment member an inferior surface of tongue turns [member] to the inside of said liquid container, and said attachment member is characterized by having opening in the core of said oscillating section.

[Claim 10] The piezoelectric device according to claim 1 characterized by said piezoelectric device detecting the consumption condition of the liquid in said liquid container by detecting change of the acoustic impedance near [said] the oscillating section.

[Claim 11] The piezoelectric device according to claim 10 characterized by detecting change of said acoustic impedance based on back EMF which said piezoelectric device generates by the residual vibration which remains in said oscillating section, and detecting the consumption condition of the liquid in said liquid container.

[Claim 12] The piezoelectric device according to claim 1 by which this oscillating section is generating-vibration to which single peak appears in resonance mode of low degree in resonance mode of vibration characterized.

[Claim 13] The liquid container characterized by being equipped with a piezoelectric device according to claim 1 to 12.

[Claim 14] The module object characterized by having the attachment structure united with the piezoelectric device according to claim 1 to 12 and said piezoelectric device for attaching said piezoelectric device in said liquid container.

[Claim 15] The module object according to claim 14 characterized by having arranged the core of said oscillating section on the center line of said overhang section including the overhang section which said attachment structure juts out inside said liquid container.

[Claim 16] The module object according to claim 15 with which said overhang section is characterized by being a cylindrical shape.

[Claim 17] The module object according to claim 16 characterized by having further the terminal electrically connected with said up electrode of said piezoelectric device, and said lower electrode.

[Claim 18] The liquid container characterized by being equipped with a module object according to claim 14 to 17.

[Claim 19] The ink cartridge characterized by holding the ink supplied to an ink jet recording apparatus in a liquid container according to claim 13 or 18.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention is detecting change of an acoustic impedance, and relates to the liquid container with which it had the piezoelectric device (actuator) for detecting the consumption condition of the liquid in the liquid container which holds liquids, such as ink, by detecting change of resonance frequency also especially in it. In more detail, the ink of a pressure generating room is made equivalent to print data with a pressure generating means, and it pressurizes, and is related with the piezoelectric device suitable for the ink jet recording apparatus which is made to breathe out an ink droplet and is printed from a nozzle orifice, a module object, a liquid container, and an ink cartridge.

[0002]

[Description of the Prior Art] An ink jet recording device carries the ink jet recording head equipped with a pressure generating means to pressurize a pressure generating room, and the nozzle orifice which carries out the regurgitation of the pressurized ink as an ink droplet from a nozzle orifice in carriage. The ink jet recording device is constituted possible [continuation of printing], supplying the ink of an ink tank to a recording head through passage. When ink is consumed, the ink tank is constituted as a removable cartridge so that a user can exchange easily.

[0003] Conventionally, there is a method of managing the time of specified quantity consumption of the ink actually being carried out etc. the approach of software integrating the amount of ink attracted by the number of regurgitation of the ink droplet in a recording head, or maintenance as a management method of ink consumption of an ink cartridge, and managing ink consumption by count, and by attaching the electrode for oil-level detection in an ink cartridge.

[0004] However, the approach of software integrating the number of regurgitation and the amount of ink of an ink droplet, and managing ink consumption on count has the problem that an error arises according to the printing gestalt in a user side etc., and gross errors arise at the time of re-wearing of the same cartridge. Moreover, there was also a problem that the error which the pressure in an ink cartridge and the viscosity of ink change with the elapsed time after opening of height with a going too far room temperature or an ink cartridge etc., and cannot be disregarded between the ink consumption on count and actual consumption will arise by the operating environment. Since the method of on the other hand managing the time of ink being consumed with an electrode can detect the amount of real of ink, it can manage an ink residue with high dependability. However, since it depends for detection of the oil level of ink on the conductivity of ink, the class of detectable ink is limited and there is a problem which the seal structure of an electrode complicates. Moreover, since noble metals good [usually] conductivity and high were used as an ingredient of an electrode, there were corrosion resistance and a problem that the manufacturing cost of an ink cartridge increased. Furthermore, since it was necessary to equip with two electrodes, the production process increased and there was also a problem that a manufacturing cost will increase as a result.

[0005]

[Problem(s) to be Solved by the Invention] Then, this invention aims at offering the piezoelectric device and module object which can solve the above-mentioned technical problem, which could detect the ink residue correctly and made complicated seal structure unnecessary and with which a liquid container is equipped. This purpose is attained by the combination of the description given in the independent term in a claim. Moreover, a subordination term specifies the further advantageous example of this invention.

[0006]

[Means for Solving the Problem] That is, a liquid container is equipped with the piezoelectric device in the 1st gestalt of this invention, it is the piezoelectric device which detects the consumption condition of the liquid in a liquid container, said piezoelectric device has the oscillating section which vibration generates according to deformation of a piezo electric crystal component, and, as for the oscillating section, it is desirable to have a symmetrical configuration to the core.

[0007] Moreover, as for the oscillating section of a piezoelectric device, it is desirable to have an almost circular configuration. Furthermore, the up electrode prepared in the top face of a piezo-electric layer and a piezo-electric layer, the lower electrode prepared in the inferior surface of tongue of a piezo-electric layer, and a top face touch a lower electrode, a piezoelectric device is equipped with the diaphragm with which at the bottom [a part of] contacts the liquid in a liquid container, and, as for the oscillating section, it is desirable that some of a piezo-electric layer, up electrodes, lower electrodes, and each diaphragms [at least] are included. Furthermore, it is desirable that each principal piece of a piezo-electric layer, an up electrode, and a lower electrode is the oscillating section and the configuration where a concentric circle is almost circular.

[0008] Moreover, as for a piezoelectric device, it is desirable to have a cavity in contact with a liquid in the location where a top face touches the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, an inferior surface of tongue is further equipped with the substrate in contact with the liquid in a liquid container, and a substrate faces the oscillating section. As for a cavity, it is desirable the oscillating section and that it is the circle configuration of a concentric circle mostly. Moreover, it is desirable that deformation of the diaphragm by residual vibration is larger than deformation of a substrate. The knot of vibration of the oscillating section may be located near the periphery section of a cavity. As for a piezoelectric device, it is desirable that a top face touches the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, have further the attachment member an inferior surface of tongue turns [member] to the inside of a liquid container, and an attachment member has opening in the core of the oscillating section. Furthermore, it is desirable that it is the liquid container with which it was equipped with the above-mentioned piezoelectric device.

[0009] As for the module object in the 2nd gestalt of this invention, it is desirable to have the attachment structure united with the above-mentioned piezoelectric device and the piezoelectric device for attaching a piezoelectric device in a liquid container.

[0010] The core of the oscillating section may be arranged on the center line of the overhang section including the overhang section which the attachment structure juts out inside a liquid container. Furthermore, the overhang section may be a cylindrical shape. You may have further the terminal which gives a driving signal to the up electrode and lower electrode of a piezoelectric device. Moreover, it is desirable that it is the liquid container with which it was equipped with the above-mentioned module object. Moreover, you may be the ink cartridge which holds the ink supplied to an ink jet recording apparatus in the above-mentioned liquid

container.

[0011] In addition, the outline of the above-mentioned invention is not what enumerated all the required descriptions of this invention, and the subcombination of these characterizing group can also be invented.

[0012]

[Embodiment of the Invention] Hereafter, this invention is explained to a detail through the gestalt of implementation of invention. Not all the combination of the description of the following operation gestalten that do not limit invention concerning a claim and are explained in the operation gestalt is necessarily indispensable for the solution means of invention.

[0013] The underlying concept of this invention is using an oscillating phenomenon, and is detecting the condition (the existence of the liquid in a liquid container, the amount of a liquid, the water level of a liquid, the class of liquid, and the presentation of a liquid being included) of the liquid in a liquid container. Some approaches can be considered as detection of the condition of the liquid in the liquid container using a concrete oscillating phenomenon. For example, an elastic wave generating means generates an elastic wave to the interior of a liquid container, and there is a method of detecting the medium in a liquid container and change of the condition by receiving the reflected wave reflected with an oil level or the wall which counters. Moreover, there is also the approach of detecting change of an acoustic impedance apart from this from the oscillation characteristic of the vibrating body. As an approach of using change of an acoustic impedance By vibrating the oscillating section of the piezoelectric device or actuator which has a piezoelectric device, and measuring back EMF produced by the residual vibration which remains in the oscillating section after that The approach of detecting change of an acoustic impedance by detecting resonance frequency or the back EMF wave amplitude, The impedance characteristic or admittance property of a liquid is measured with impedance analyzers, such as a measurement machine, for example, a propagation circuit etc., and there is the approach of measuring change by the frequency of the current value when giving a current value, an electrical-potential-difference value change, or vibration to a liquid or an electrical-potential-difference value. Hereafter, the detail of the principle of operation of a piezoelectric device or an actuator is explained.

[0014] Drawing 1 and drawing 2 show the detail and equal circuit of an actuator 106 which are 1 operation gestalt of a piezoelectric device. An actuator here is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container. It is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container because resonance frequency detects by residual vibration especially. Drawing 1 (A) is the expansion top view of an actuator 106. Drawing 1 (B) shows the B-B cross section of an actuator 106. Drawing 1 (C) shows the C-C cross section of an actuator 106. Furthermore, drawing 2 (A) and drawing 2 (B) show the equal circuit of an actuator 106. Moreover, drawing 2 (C) and drawing 2 (D) show the circumference containing the actuator 106 when ink is filled in the ink cartridge, respectively, and its equal circuit, and drawing 2 (E) and drawing 2 (F) show the circumference containing the actuator 106 in case there is no ink into an ink cartridge, respectively, and its equal circuit.

[0015] The substrate 178 with which an actuator 106 has the opening 161 of a circle configuration in the center mostly, The diaphragm 176 arranged in one field (henceforth a front face) of a substrate 178 so that opening 161 may be covered, The piezo-electric layer 160 arranged at the front-face side of a diaphragm 176, and the up electrode 164 and the lower electrode 166 which inserts the piezo-electric layer 160 from both, It has the auxiliary electrode

172 which is arranged between the up electrode terminal 168 electrically combined with the up electrode 164, the lower electrode terminal 170 electrically combined with the lower electrode 166, and the up electrode 164 and the up electrode terminal 168, and combines both electrically. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 have a circular part as each principal part. Each circular part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device.

[0016] A diaphragm 176 is formed in the front face of a substrate 178 so that opening 161 may be covered. A cavity 162 is formed of the opening 161 of a diaphragm 176, the facing part, and the opening 161 of the front face of a substrate 178. With the piezoelectric device of a substrate 178, the field (henceforth a rear face) of the opposite side faces the liquid-container side, and the cavity 162 is constituted so that a liquid may be contacted, even if a liquid enters in a cavity 162, a liquid does not leak to the front-face side of a substrate 178 -- as -- a diaphragm 176 -- a substrate 178 -- receiving -- liquid -- it is attached densely.

[0017] The front face of a diaphragm 176, i.e., a liquid container, is located in the field of the opposite side, and the lower electrode 166 is attached so that the core of a circular part and the core of opening 161 which are the principal part of the lower electrode 166 may be mostly in agreement. In addition, it is set up so that the area of the circular part of the lower electrode 166 may become smaller than the area of opening 161. On the other hand, the piezo-electric layer 160 is formed in the front-face side of the lower electrode 166 so that the core of the circular part and the core of opening 161 may be mostly in agreement. The area of the circular part of the piezo-electric layer 160 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of opening 161.

[0018] On the other hand, it is formed in the front-face side of the piezo-electric layer 160 so that the core of a circular part and the core of opening 161 that the up electrode 164 is the principal part may be mostly in agreement. The area of the circular part of the up electrode 164 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of the circular parts of opening 161 and the piezo-electric layer 160.

[0019] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0020] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up

electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0021] The core of the circular parts of the piezo-electric layer 160 which forms a piezoelectric device, the up electrode 164, and the lower electrode 166 corresponds with the core of opening 161 mostly. moreover, the core of the opening 161 of a circle configuration of determining the vibrating part of a diaphragm 176 -- an actuator 106 -- it is mostly prepared in the core.

Therefore, the core of the oscillating section of an actuator 106 is mostly in agreement with the core of an actuator. Furthermore, since the principal piece of a piezoelectric device and the vibrating part of a diaphragm 176 have a circular configuration, the oscillating section of an actuator 106 is a symmetrical configuration to the core of an actuator 106.

[0022] Since the oscillating section is a symmetrical configuration, it can be prevented from exciting an unnecessary vibration produced from the asymmetry of structure to the core of an actuator 106. Therefore, the detection precision of resonance frequency improves. Furthermore, to an actuator core, since the oscillating section is a symmetrical configuration, it is easy to manufacture it and it can make small dispersion in the configuration for every piezoelectric device. Therefore, dispersion in the resonance frequency for every piezoelectric device becomes small. Moreover, since the oscillating section is an isotropic configuration, it is hard to be influenced of dispersion in immobilization in the case of adhesion. A liquid container is pasted equally. Therefore, the mounting nature to the liquid container of an actuator 106 is good.

[0023] Furthermore, since the vibrating part of a diaphragm 176 has a circular configuration, in the resonance mode of the residual vibration of the piezo-electric layer 160, the resonance mode of a low degree, for example, primary, becomes dominant, and a single peak appears. Therefore, since a peak and a noise are clearly distinguishable, resonance frequency is clearly detectable. Moreover, by enlarging area of the vibrating part of the diaphragm 176 of a circular configuration, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and can improve the precision of detection of resonance frequency further.

[0024] The variation rate by vibration of a diaphragm 176 is farther [than the variation rate by vibration of a substrate 178] large. Compliance is small, namely, an actuator 106 has the two-layer structure of the substrate 178 which is hard to displace by vibration, and the diaphragm 176 which compliance is large, namely, is easy to displace by vibration. According to this two-layer structure, since the variation rate of the diaphragm 176 by vibration can be enlarged certainly being fixed to a liquid container by the substrate 178, the difference of the back EMF wave

amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and the precision of detection of resonance frequency can be improved. Furthermore, since the compliance of a diaphragm 176 is large, attenuation of vibration becomes small and the precision of detection of resonance frequency can be improved. Moreover, the knot of vibration of an actuator 106 is located near the edge of the periphery section 161 of a cavity 162, i.e., opening.

[0025] The up electrode terminal 168 is formed in the front-face side of a diaphragm 176 so that it may connect with the up electrode 164 electrically through an auxiliary electrode 172. On the other hand, the lower electrode terminal 170 is formed in the front-face side of a diaphragm 176 so that it may connect with the lower electrode 166 electrically. Since the up electrode 164 is formed in the front-face side of the piezo-electric layer 160, it needs to have a level difference equal to the sum of the thickness of the piezo-electric layer 160, and the thickness of the lower electrode 166 while connecting with the up electrode terminal 168. The connection condition of the up electrode 164 and the up electrode terminal 168 becomes weak, and forming this level difference only with the up electrode 164 has risk of cutting, even if it is difficult and possible in a loan. Then, the up electrode 164 and the up electrode terminal 168 are connected, using an auxiliary electrode 172 as an auxiliary member. It becomes possible for the piezo-electric layer 160 and the up electrode 164 to serve as structure supported by the auxiliary electrode 172, and to be able to obtain a desired mechanical strength, and to ensure connection between the up electrode 164 and the up electrode terminal 168 by doing in this way.

[0026] In addition, the oscillating field which faces a piezoelectric device and the piezoelectric device of the diaphragms 176 is the oscillating section which actually vibrates in an actuator 106. Moreover, as for the member contained in an actuator 106, being formed in one is desirable by being calcinated mutually. By forming an actuator 106 in one, the handling of an actuator 106 becomes easy. Furthermore, an oscillation characteristic improves by raising the reinforcement of a substrate 178. That is, by raising the reinforcement of a substrate 178, only the oscillating section of an actuator 106 vibrates and any parts other than the oscillating section do not vibrate among actuators 106. Moreover, in order for any parts other than the oscillating section of an actuator 106 not to vibrate, it can attain by making the piezoelectric device of an actuator 106 thinly and small, and making a diaphragm 176 thin to raising the reinforcement of a substrate 178.

[0027] It is desirable to use the lead loess piezoelectric film which does not use PZT (PZT), the PZT lanthanum (PLZT), or lead as an ingredient of the piezo-electric layer 160, and it is desirable to use a zirconia or an alumina as an ingredient of a substrate 178. Moreover, it is desirable to use the same ingredient as a substrate 178 for a diaphragm 176. Metals, such as the ingredient which has conductivity, for example, gold, silver, copper, platinum, aluminum, and nickel, can be used for the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170.

[0028] The actuator 106 constituted as mentioned above is applicable to the container which holds a liquid. For example, the container which held the penetrant remover for washing the ink cartridge and ink tank which are used for an ink jet recording apparatus, or a recording head can be equipped.

[0029] The predetermined location of a liquid container is equipped with the actuator 106 shown in drawing 1 and drawing 2 so that the liquid held in a liquid container in a cavity 162 may be contacted. When the liquid is fully held in the liquid container, the inside of a cavity 162 and its outside are filled by the liquid. On the other hand, if the liquid of a liquid container is consumed

and an oil level descends below to the stowed position of an actuator, a liquid does not exist in a cavity 162, or a liquid remains only in a cavity 162, and it will be in the condition that a gas exists on the outside. An actuator 106 detects the difference of an acoustic impedance as it is [originating in change of this condition, and] few. By it, an actuator 106 can detect whether it is in the condition that the liquid is fully held in the liquid container, or it is in the condition that a certain liquid more than fixed was consumed. Furthermore, an actuator 106 can also detect the class of liquid in a liquid container.

[0030] Here explains the principle of the oil-level detection by the actuator.

[0031] In order to detect change of the acoustic impedance of a medium, the impedance characteristic or admittance property of a medium is measured. A propagation circuit can be used when measuring an impedance characteristic or an admittance property. A propagation circuit impresses a fixed electrical potential difference to a medium, and measures the current which changes a frequency and flows to a medium. Or a propagation circuit supplies a fixed current to a medium, and measures the electrical potential difference which changes a frequency and is impressed to a medium. The current value or electrical-potential-difference value change measured by the propagation circuit shows change of an acoustic impedance. Moreover, change of the frequency f_m from which a current value or an electrical-potential-difference value serves as the maximum or the minimum also shows change of an acoustic impedance.

[0032] Apart from the above-mentioned approach, an actuator can detect change of the acoustic impedance of a liquid using change of only resonance frequency. A piezoelectric device can be used, when using the approach of detecting resonance frequency by measuring back EMF produced by the residual vibration which remains in the oscillating section, as an approach of using change of the acoustic impedance of a liquid after the oscillating section of an actuator vibrates. A piezoelectric device is a component which generates back EMF by the residual vibration which remains in the oscillating section of an actuator, and the magnitude of back EMF changes with the amplitude of the oscillating section of an actuator. Therefore, it is easy to carry out detection, so that the amplitude of the oscillating section of an actuator is large. Moreover, the period from which the magnitude of back EMF changes with the frequencies of the residual vibration in the oscillating section of an actuator changes. Therefore, the frequency of the oscillating section of an actuator is equivalent to the frequency of back EMF. Here, resonance frequency says the frequency in the resonance state with the medium which touches the oscillating section and the oscillating section of an actuator.

[0033] In order to obtain resonance frequency f_s , the Fourier transform of the wave acquired by the back EMF measurement in case the oscillating section and a medium are the resonance state is carried out. Since vibration of an actuator is accompanied not by deformation of only an one direction but by various deformation, such as a deflection and expanding, it has various frequencies including resonance frequency f_s . Therefore, the Fourier transform of the wave of back EMF in case a piezoelectric device and a medium are the resonance state is carried out, and resonance frequency f_s is judged by specifying the most dominant frequency component.

[0034] The admittance of a medium of a frequency f_m is a frequency in case the maximum or an impedance is the minimum. If it is resonance frequency f_s , a frequency f_m will produce few errors to resonance frequency f_s by dielectric loss or a mechanical loss of a medium etc. However, since time and effort is taken, generally deriving resonance frequency f_s from the frequency f_m surveyed replaces with and uses a frequency f_m for resonance frequency. Here, an actuator 106 can detect an acoustic impedance at least in inputting the output of an actuator 106 into a propagation circuit.

[0035] It is proved to be the approach of measuring resonance frequency f_s by experiment by measuring the approach of measuring the impedance characteristic or admittance property of a medium, and measuring a frequency f_m , and back EMF produced by residual vibration vibration in the oscillating section of an actuator that there is almost no difference in the resonance frequency specified as be alike.

[0036] The oscillating field of an actuator 106 is a part which constitutes the cavity 162 determined by opening 161 among diaphragms 176. When the liquid is fully held in the liquid container, in a cavity 162, a liquid is filled and an oscillating field contacts the liquid in a liquid container. On the other hand, when there is no enough liquid into a liquid container, an oscillating field does not contact a liquid in contact with the liquid which remained in the cavity in a liquid container, but contacts a gas or a vacuum.

[0037] A cavity 162 is formed in the actuator 106 of this invention, and it can design so that the liquid in a liquid container may remain in the oscillating field of an actuator 106 by it. The reason is as follows.

[0038] Although there is an oil level of the liquid in a liquid container caudad depending on [stowed position / of an actuator] whenever [installation location / to the liquid container of an actuator /, or setting-angle], a liquid may adhere to the oscillating field of an actuator. When the actuator has detected the existence of a liquid only by the existence of the liquid in an oscillating field, the liquid adhering to the oscillating field of an actuator bars exact detection of the existence of a liquid. for example, the time of the condition that there is an oil level caudad rather than the stowed position of an actuator -- both-way migration of carriage etc. -- a liquid container -- rocking -- a liquid -- a wave -- inside, if a drop adheres to an oscillating field, an actuator will make a judgment which if liquids of enough are in a liquid container mistook. Then, malfunction of an actuator can be prevented, even if it is the case where a liquid is remained conversely there and an oil level is [a liquid container rocks and] choppy by preparing positively the cavity designed so that the existence of a liquid might be detected correctly. Thus, malfunction can be prevented by using the actuator which has a cavity.

[0039] Moreover, as shown in drawing 2 (E), there is no liquid into a liquid container and let the case where the liquid in a liquid container remains in the cavity 162 of an actuator 106 be the threshold of the existence of a liquid. That is, there is no liquid around a cavity 162 and it judges that he has no ink when there are few liquids in a cavity than this threshold, a liquid is around a cavity 162, and when there are more liquids than this threshold, it is judged as those with ink. For example, when the side attachment wall of a liquid container is equipped with an actuator 106, the case where the liquid in a liquid container is below the stowed position of an actuator is judged to have no ink, and the case where the liquid in a liquid container is above the stowed position of an actuator is judged to be those with ink. Thus, even if it is a time of the ink in a cavity drying and ink being lost by setting up a threshold, it judges that he has no ink, and since a threshold is not exceeded even if ink adheres to a cavity again in the shake of carriage etc. at the place whose ink in a cavity was lost, it can be judged that he has no ink.

[0040] Here, the actuation and the principle which detect the condition of the liquid in a liquid container from the resonance frequency of the medium and the oscillating section of an actuator 106 by measurement of back EMF are explained, referring to drawing 1 and drawing 2. In an actuator 106, an electrical potential difference is impressed to the up electrode 164 and the lower electrode 166 through the up electrode terminal 168 and the lower electrode terminal 170, respectively. Electric field arise into the part pinched by the up electrode 164 and the lower electrode 166 among the piezo-electric layers 160. The piezo-electric layer 160 deforms by the

electric field. When the piezo-electric layer 160 deforms, the oscillating field of the diaphragms 176 oscillates flexurally. After the piezo-electric layer 160 deforms, flexural oscillation remains in the oscillating section of an actuator 106 for the time being.

[0041] Residual vibration is the free vibration of the oscillating section of an actuator 106, and a medium. Therefore, by making into pulse shape or a square wave the electrical potential difference impressed to the piezo-electric layer 160, after impressing an electrical potential difference, the resonance state of the oscillating section and a medium can be acquired easily. Residual vibration also deforms the piezo-electric layer 160 in order to vibrate the oscillating section of an actuator 106. Therefore, the piezo-electric layer 160 generates back EMF. The back EMF is detected through the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170. Since resonance frequency can be specified, the condition of the liquid in a liquid container is detectable with detected back EMF.

[0042] Generally, it is resonance frequency $f_s = 1/(2\pi \sqrt{M \cdot Cact})$ (formula 1)

It is come out and expressed. Here, M is the sum of the inertia Mact of the oscillating section, and addition inertia M'. Cact is the compliance of the oscillating section.

[0043] Drawing 1 (C) is the sectional view of the actuator 106 when ink does not remain in a cavity in this example. Drawing 2 (A) and drawing 2 (B) are the oscillating section of the actuator 106 when ink does not remain in a cavity, and the equal circuit of a cavity 162.

[0044] Mact should be the product of the thickness of the oscillating section, and the consistency of the oscillating section in the area of the oscillating section, and should show it further to a detail at drawing 2 (A). $Mact = Mpzt + Melectrode1 + Melectrode2 + Mvib$ (formula 2)

It is expressed. Here, Mpzt is the product of the thickness of the piezo-electric layer 160 and the consistency of the piezo-electric layer 160 in the oscillating section in the area of the piezo-electric layer 160. Melectrode1 is the product of the thickness of the up electrode 164 and the consistency of the up electrode 164 in the oscillating section in the area of the up electrode 164. Melectrode2 is the product of the thickness of the lower electrode 166 and the consistency of the lower electrode 166 in the oscillating section in the area of the lower electrode 166. Mvib is the product of the thickness of a diaphragm 176 and the consistency of a diaphragm 176 in the oscillating section in the area of the oscillating field of a diaphragm 176. However, in this example, although each area of the oscillating field of the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176 has the above size relation, a minute thing is desirable [the difference of a mutual area], so that Mact can be computed from the thickness, the consistency, and area as the whole oscillating section. Moreover, as for parts other than the circular part which are those principal parts, in this example, it is desirable in the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 that it is so minute that it can ignore to the principal part. Therefore, in an actuator 106, Mact is the sum of each inertia of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176. Moreover, Compliance Cact is the compliance of the part formed of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176.

[0045] In addition, although drawing 2 (A), drawing 2 (B), drawing 2 (D), and drawing 2 (F) show the oscillating section of an actuator 106, and the equal circuit of a cavity 162, in these equal circuits, Cact shows the compliance of the oscillating section of an actuator 106. Cpzt, Celectrode1 and Celectrode2, and Cvib show the compliance of the piezo-electric layer 160 in the oscillating section, the up electrode 164, the lower electrode 166, and a diaphragm 176, respectively. Cact is expressed with the following formulas 3.

[0046]

$1 - \text{Cact} = (1 - \text{Cpzt}) + (1 - \text{Celectrode1}) + (1 - \text{Celectrode2}) + (1 - \text{Cvib})$ (formula 3)

From a formula 2 and a formula 3, drawing 2 (A) can also be expressed like drawing 2 (B).

[0047] Compliance Cact expresses the volume which can receive a medium according to the deformation when putting a pressure on the unit area of the oscillating section. Moreover, Compliance Cact may say that it expresses the ease of carrying out of deformation.

[0048] A liquid is fully held in a liquid container and drawing 2 (C) shows the sectional view of the actuator 106 in case the liquid is filled around the oscillating field of an actuator 106. A liquid is fully held in a liquid container and M'max of drawing 2 (C) expresses the maximum of an addition inertance in case the liquid is filled around the oscillating field of an actuator 106. M'max is [0049].

$M'max = (\pi \cdot \rho / (2 \cdot k^3)) \cdot (2 \cdot (2 \cdot k \cdot a)^3 / (3 \cdot \pi)) / (\pi \cdot a^2)$ (formula 4)

(a is [the consistency of a medium and k of the radius of the oscillating section and ρ] the wave numbers.)

[0050] It is come out and expressed. In addition, a formula 4 is materialized when the radius a of the oscillating field of an actuator 106 is circular. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. As shown in a formula 4, M'max changes with the radius a of the oscillating section, and the consistencies ρ of a medium a lot.

[0051] The wave number k is $k = 2 \cdot \pi \cdot \text{fact} / c$. (formula 5)

(fact is the resonance frequency of the oscillating section when the liquid is not touching.) c is the rate of the sound which spreads the inside of a medium.

[0052] It is come out and expressed.

[0053] A liquid is fully held in a liquid container and drawing 2 (D) shows the oscillating section of the actuator 106 in the case of being drawing 2 (C) with which the liquid is filled around the oscillating field of an actuator 106, and the equal circuit of a cavity 162.

[0054] Although the liquid of a liquid container is consumed and drawing 2 (E) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the sectional view of the actuator 106 when the liquid remains is shown. A formula 4 is a formula showing the greatest inertance M'max determined from the consistency ρ of ink etc., when the liquid is filled by the liquid container. It is [0055] when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum on the other hand, the liquid in a liquid container having been consumed and a liquid remaining in a cavity 162. $M' = \rho \cdot t / S$ (formula 6)

It can express. t is the thickness of the medium in connection with vibration. S is the area of the oscillating field of an actuator 106. It is $S = \pi \cdot a^2$ when the radius a of this oscillating field is circular. Therefore, addition inertance M' follows a formula 4, when a liquid is fully held in a liquid container and the liquid is filled around the oscillating field of an actuator 106. On the other hand, a liquid is consumed, and a formula 6 is followed when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum, a liquid remaining in a cavity 162.

[0056] Here, although the liquid of a liquid container is consumed and there is no liquid around the oscillating field of an actuator 106 like drawing 2 (E), addition inertance M' when the liquid remains in the cavity 162 of an actuator 106 is made into M'cav for convenience, and it distinguishes from addition inertance M'max in case the liquid is filled around the oscillating field of an actuator 106.

[0057] Although the liquid of a liquid container is consumed and drawing 2 (F) does not have a

liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the oscillating section of the actuator 106 in the case of being drawing 2 (E) in which the liquid remains, and the equal circuit of a cavity 162 are shown.

[0058] Here, the parameters related to the condition of a medium are the consistency ρ of a medium, and thickness t of a medium in a formula 6. When the liquid is fully held in the liquid container, a liquid contacts the oscillating section of an actuator 106, when the liquid is not fully held in the liquid container, a liquid remains inside a cavity or a gas or a vacuum contacts the oscillating section of an actuator 106. The surrounding liquid of an actuator 106 is consumed, if the addition inductance in the process which shifts to M'_{cav} of drawing 2 (E) from M'_{max} of drawing 2 (C) is made into M'_{var} , since thickness t of the consistency ρ of a medium and a medium changes, addition inductance M'_{var} will change and resonance frequency f_s will also change with the hold conditions of the liquid in a liquid container. Therefore, the existence of the liquid in a liquid container is detectable by specifying resonance frequency f_s . When M'_{cav} is expressed using a formula 6, depth d of a cavity is substituted for t of a formula 6, and it is [0059].

$$M'_{cav} = \rho \cdot d / S \text{ (formula 7)}$$

It becomes.

[0060] Moreover, since a consistency ρ changes with differences in a presentation even if a medium is a liquid with which classes differ mutually, addition inductance M' changes and resonance frequency f_s also changes. Therefore, the class of liquid is detectable by specifying resonance frequency f_s . In addition, when either ink or air contacts and it is not intermingled in the oscillating section of an actuator 106, the difference of M' can be detected even if it calculates by the formula 4.

[0061] Drawing 3 (A) is a graph which shows relation with the resonance frequency f_s of the amount of the ink in an ink tank, ink, and the oscillating section. Here, ink is explained as one example of a liquid. An axis of ordinate shows resonance frequency f_s , and an axis of abscissa shows the amount of ink. When an ink presentation is fixed, resonance frequency f_s rises with the fall of an ink residue.

[0062] When ink is fully held in an ink container and ink is filled around the oscillating field of an actuator 106, the maximum addition inductance M'_{max} serves as a value expressed to a formula 4. On the other hand, ink is consumed, and when ink is not filled around the oscillating field of an actuator 106, a liquid remaining in a cavity 162, addition inductance M'_{var} is computed by the formula 6 based on thickness t of a medium. t in a formula 6 can also detect the process in which ink is gradually consumed by being small in d (referring to drawing 1 (B)) of the cavity 162 of an actuator 106, namely, making a substrate 178 thin enough since it is the thickness of the medium in connection with vibration (refer to drawing 2 (C)). Here, t considers as the thickness of the ink in connection with vibration, and sets $t_{ink-max}$ to t in M'_{max} . For example, an actuator 106 is arranged almost horizontally to the oil level of ink on the base of an ink cartridge. If ink is consumed and the oil level of ink reaches below the height of t from an actuator 106, M'_{var} will change with formulas 6 gradually and resonance frequency f_s will change with formulas 1 gradually. Therefore, as long as the oil level of ink is within the limits of t , as for an actuator 106, the consumption condition of ink is detectable gradually.

[0063] Moreover, according to the location of the oil level by consumption of ink, S in a formula 6 changes by making the oscillating field of an actuator 106 greatly or long, and arranging perpendicularly. Therefore, an actuator 106 can also detect the process in which ink is consumed gradually. For example, an actuator 106 is arranged almost perpendicularly to the oil level of ink

on the side attachment wall of an ink cartridge. If ink is consumed and the oil level of ink arrives at the oscillating field of an actuator 106, since addition inertance M' will decrease with the fall of water level, resonance frequency f_s increases gradually by the formula 1. Therefore, as for an actuator 106, the oil level of ink can detect the consumption condition of ink gradually, as long as it is within the limits of path 2a (refer to drawing 2 (C)) of a cavity 162.

[0064] The curve X of drawing 3 (A) expresses relation with the resonance frequency f_s of the amount of the ink held in the ink tank the case where the cavity 162 of an actuator 106 is made shallow enough, and at the time of making the oscillating field of an actuator 106 greatly enough or long, ink, and the oscillating section. While the amount of the ink in an ink tank decreases, he can understand signs that the resonance frequency f_s of ink and the oscillating section changes gradually.

[0065] The case where the process in which ink is consumed gradually is detectable in a detail is a case where both the liquids and gases from which a consistency differs mutually exist, and it is concerned with vibration, in the circumference of the oscillating field of an actuator 106 more. While liquids decrease in number, a gas increases the medium on the circumference of an oscillating field of an actuator 106, and in connection with vibration, as ink is consumed gradually. For example, it is the case where an actuator 106 is horizontally arranged to the oil level of ink, and when $tink$ is smaller than $tink_{max}$, the medium in connection with vibration of an actuator 106 contains both ink and a gas. Therefore, it is [0066] when the condition of having become below M'_{max} of a formula 4 when it was the area S of the oscillating field of an actuator 106 is expressed with the additional mass of ink and a gas.

$M' = M'_{air} + M'_{ink} = \rho_{air} t_{air} / S + \rho_{ink} t_{ink} / S$ (formula 8)

It becomes. Here, M'_{air} is the inertance of air and M'_{ink} is the inertance of ink. ρ_{air} is the consistency of air and ρ_{ink} is the consistency of ink. t_{air} is the thickness of the air in connection with vibration, and t_{ink} is the thickness of the ink in connection with vibration. When the actuator 106 is arranged almost horizontally to the oil level of ink as liquids decrease in number among the media in connection with the vibration in the circumference of an oscillating field of an actuator 106 and a gas increases, t_{air} increases and t_{ink} decreases. By it, M'_{var} decreases gradually and resonance frequency increases gradually. Therefore, the amount of the ink which remains in an ink tank, or the consumption of ink is detectable. In addition, in a formula 7, it is the formula of only the consistency of a liquid because the case of being so small that the consistency of air being disregarded is assumed to the consistency of a liquid.

[0067] When the actuator 106 is arranged almost perpendicularly to the oil level of ink, the media in connection with vibration of an actuator 106 are considered to be the field of only ink, and the equal circuit (not shown) of juxtaposition of the medium in connection with vibration of an actuator 106 with a gaseous field among the oscillating fields of an actuator 106. It is [0068], when the medium in connection with vibration of an actuator 106 sets area of the field of only ink to S_{air} and the medium in connection with vibration of an actuator 106 sets area of a gaseous field to S_{air} .

$1/M' = 1/M'_{air} + 1/M'_{ink} = S_{air} / (\rho_{air} t_{air}) + S_{ink} / (\rho_{ink} t_{ink})$ (formula 9)

It becomes.

[0069] In addition, a formula 9 is applied when ink is not held at the cavity of an actuator 106. About the case where ink is held at the cavity of an actuator 106, it is calculable with a formula 7, a formula 8, and a formula 9.

[0070] On the other hand, the oil level of ink will detect an upper location or a bottom location from the stowed position of an actuator rather than a substrate 178 is thick, namely, depth d of a

cavity 162 is deep, and it detects the process in which ink decreases in number gradually in practice, when d uses an actuator with a very small oscillating field as compared with the case of being comparatively close to thickness $t_{ink-max}$ of a medium, and the height of a liquid container. When it puts in another way, the existence of the ink in the oscillating field of an actuator will be detected. For example, the curve Y of drawing 3 (A) shows relation with the resonance frequency f_s of the amount of the ink in the ink tank in the case of a small circular oscillating field, ink, and the oscillating section. Between the amounts Q of ink before and after the oil level of the ink in an ink tank passes through the stowed position of an actuator, signs that the resonance frequency f_s of ink and the oscillating section is changing violently are shown. From this, it is detectable in an ink tank whether ink is carrying out specified quantity survival.

[0071] A diaphragm 176 is contacting a liquid and directly, and since the method of detecting the existence of a liquid using an actuator 106 detects the existence of ink, compared with the approach of calculating the consumption of ink with software, its detection precision is high. Furthermore, although the approach conductivity detects the existence of ink is influenced according to the attaching position to a liquid container, and the class of ink using an electrode, the approach of detecting the existence of a liquid using an actuator 106 is not influenced according to the attaching position to a liquid container, and the class of ink. Furthermore, since the both sides of detection of the existence of a liquid can be considered as an oscillation using the single actuator 106, the number of the sensors attached in a liquid container as compared with the approach of carrying out oscillation and detection of the existence of a liquid using a different sensor can be decreased. Therefore, a liquid container can be manufactured cheaply. Furthermore, it can be [sound / which an actuator 106 generates working] quiet by setting the oscillation frequency of the piezo-electric layer 160 as a non-audible field.

[0072] Drawing 3 (B) shows relation with the resonance frequency f_s of the consistency of the ink in the curve Y of drawing 3 (A), ink, and the oscillating section. Ink is mentioned as an example of a liquid. Since an addition inertance will become large if an ink consistency becomes high as shown in drawing 3 (B), resonance frequency f_s falls. That is, resonance frequency f_s changes with classes of ink. Therefore, in case it is re-filled up with ink by measuring resonance frequency f_s , it can check whether the ink in which consistencies differed is mixed.

[0073] That is, the ink tank which holds the ink in which classes differ mutually is discriminable.

[0074] Then, even if the liquid in a liquid container is the state of the sky, the conditions which can detect correctly the condition of a liquid when setting up the size and the configuration of a cavity so that a liquid may remain in the cavity 162 of an actuator 106 are explained in full detail. If the condition of a liquid can be detected when the liquid is filled in the cavity 162, an actuator 106 can detect the condition of a liquid, even if it is the case where the liquid is not filled in the cavity 162.

[0075] Resonance frequency f_s is a function of Inertance M. Inertance M is the sum of the inertance M_{act} of the oscillating section, and addition inertance M' . Here, addition inertance M' is related to the condition of a liquid. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. That is, the increment of the mass of the oscillating section by absorbing a medium seemingly by vibration of the oscillating section is said.

[0076] Therefore, when M'_{cav} is larger than M'_{max} in a formula 4, all the media absorbed seemingly are liquids which remain in a cavity 162. Therefore, it is the same as the condition that the liquid is filled in the liquid container. In this case, since M' does not change, resonance frequency f_s does not change, either. Therefore, an actuator 106 can detect the condition of the

liquid in a liquid container.

[0077] On the other hand, when M'_{cav} is smaller than M'_{max} in a formula 4, the medium absorbed seemingly is the gas or vacuum in the liquid which remains in a cavity 162, and a liquid container. Since M' changes unlike the condition that the liquid is filled in the liquid container at this time, resonance frequency f_s changes. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.

[0078] That is, the liquid in a liquid container is the state of the sky, and when a liquid remains in the cavity 162 of an actuator 106, the conditions on which an actuator 106 can detect the condition of a liquid correctly are that M'_{cav} is smaller than M'_{max} . In addition, condition $M'_{max} > M'_{cav}$ to which an actuator 106 can detect the condition of a liquid correctly is not concerned with the configuration of a cavity 162.

[0079] Here, M'_{cav} is the capacity of a cavity 162, and the mass of the liquid of an almost equal capacity. Therefore, an actuator 106 can express the conditions which can detect the condition of a liquid correctly as conditions for the capacity of a cavity 162 from the inequality of $M'_{max} > M'_{cav}$. For example, it is [0080], when the radius of the opening 161 of the cavity 162 of a circle configuration is set to a and the depth of a cavity 162 is set to d . $M'_{max} > \rho \cdot d \cdot \pi a^2$ (formula 10)

It comes out. It is [0081] when a formula 10 is developed. $a/d > 3 \cdot \pi / 8$ (formula 11)

The conditions to say are searched for. In addition, when the configuration of a cavity 162 is circular, a formula 10 and a formula 11 are restricted and are materialized. If πa^2 in a formula 10 is calculated by replacing it with the area using the formula of M'_{max} when not being circular, the relation between dimensions, such as width of face of a cavity and die length, and the depth can be drawn.

[0082] Therefore, if it is the actuator 106 which has the cavity 162 which are the radius a of the opening 161 which fills a formula 11, and depth [of a cavity 162] d , even if the liquid in a liquid container is the state of the sky and it is the case where a liquid remains in a cavity 162, the condition of a liquid can be detected, without incorrect-operating.

[0083] It can be said that the approach of measuring back EMF generated in an actuator 106 by residual vibration has detected change of an acoustic impedance at least since addition inductance M' also influences an acoustic-impedance property.

[0084] Moreover, according to this example, back EMF which an actuator 106 generates vibration and generates in an actuator 106 by subsequent residual vibration is measured. However, it is not necessarily required for the oscillating section of an actuator 106 to give vibration to a liquid by its vibration by driver voltage. That is, even if the oscillating section does not oscillate itself, the piezo-electric layer 160 bends and deforms by vibrating with the liquid of a certain range in contact with it. This residual vibration makes the piezo-electric layer 160 generate the back EMF electrical potential difference, and transmits that back EMF electrical potential difference to the up electrode 164 and the lower electrode 166. The condition of a medium may be detected by using this phenomenon. For example, it may set to an ink jet recording apparatus, and the condition of an ink tank or the ink of the interior may be detected using vibration around the oscillating section of the actuator generated by vibration by the reciprocating motion of the carriage by the scan of the print head at the time of printing.

[0085] Drawing 4 (A) And drawing 4 (B) shows the wave of the residual vibration of an actuator 106 after vibrating an actuator 106, and the measuring method of residual vibration. the ink in the stowed position level of the actuator 106 in an ink cartridge — the upper and lower sides of water level are detectable with frequency change of the residual vibration after an actuator 106

oscillates, and change of the amplitude. Drawing 4 (A) And in drawing 4 (B), an axis of ordinate shows the electrical potential difference of back EMF generated by the residual vibration of an actuator 106, and an axis of abscissa shows time amount. By the residual vibration of an actuator 106, it is drawing 4 R> 4 (A). And as shown in drawing 4 (B), the wave of the analog signal of an electrical potential difference occurs. Next, an analog signal is changed into the digital numeric value corresponding to the frequency of a signal.

[0086] In the example shown in drawing 4 (A) and drawing 4 (B), the existence of ink is detected by measuring the time amount which four pulses to 8 pulse eye produce from 4 pulse eye of an analog signal.

[0087] More, in a detail, after an actuator 106 oscillates, the count which crosses the predetermined reference voltage set up beforehand from a low-battery side to a high-voltage side is counted. The between from four counts to eight counts is set to High for a digital signal, and the time amount from four counts to eight counts is measured by the predetermined clock pulse.

[0088] Drawing 4 (A) is a wave in case a liquid ink side is in a high order rather than the stowed position level of an actuator 106. On the other hand, drawing 4 (B) is a wave in case there is no ink in the stowed position level of an actuator 106. When drawing 4 R> 4 (A) is compared with drawing 4 (B), in drawing 4 (A), a ***** understands the time amount from four counts to eight counts from drawing 4 (B). A paraphrase changes the time amount from four counts to eight counts by the existence of ink. The consumption condition of ink is detectable using a difference of this time amount. After vibration of an actuator 106 is stabilized, it counts for beginning measurement from 4 count eye of an analog wave. What it was presupposed that it is from 4 count eye is a mere example, and may count from the count of arbitration. Here, the signal from 4 count eye to 8 count eye is detected, and the time amount from 4 count eye to 8 count eye is measured by the predetermined clock pulse. It asks for resonance frequency by it. As for a clock pulse, it is desirable that it is the pulse of a clock equal to the clock for controlling the semiconductor memory attached in an ink cartridge. In addition, there is no need of measuring the time amount to 8 count eye, and it may be counted to the count of arbitration. In drawing 4, although the time amount from 4 count eye to 8 count eye is measured, according to the circuitry which detects a frequency, the time amount in a different counting interval may be detected.

[0089] For example, when fluctuation of the amplitude of a peak is small, in order the quality of ink is stable, and to gather the rate of detection, you may ask for resonance frequency by detecting the time amount from 4 count eye to 6 count eye. Moreover, the quality of ink is unstable, and when fluctuation of the amplitude of a pulse is large, in order to detect residual vibration correctly, the time amount from 4 count eye to 12 count eye may be detected.

[0090] Moreover, the wave number of the voltage waveform of back EMF within a predetermined period may be counted as other examples (not shown). It can ask for resonance frequency also by this approach. More, in a detail, after an actuator 106 oscillates, only a predetermined period sets a digital signal to High, and the count which crosses predetermined reference voltage from a low-battery side to a high-voltage side is counted. The existence of ink is detectable by measuring the number of counts.

[0091] Furthermore, the back EMF wave amplitudes differ by the case where there are not a case where ink is filled in the ink cartridge, and ink into an ink cartridge so that drawing 4 (A) and drawing 4 (B) may be compared and understood. Therefore, the consumption condition of the ink in an ink cartridge may be detected also by measuring the back EMF wave amplitude, without asking for resonance frequency. Top-most vertices and drawing 4 (B) of the back EMF

wave [detail] of drawing 4 $R > 4$ (A) more Reference voltage is set up between the top-most vertices of the back EMF wave. When a digital signal is set to High at predetermined time and the back EMF wave crosses reference voltage after the actuator 106 oscillated, it is judged that there is no ink. When the back EMF wave does not cross reference voltage, it is judged that there is ink.

[0092] Drawing 5 shows the manufacture approach of an actuator 106. Two or more actuators 106 (the example of drawing 5 four pieces) are formed in one. The actuator 106 shown in drawing 6 is manufactured by cutting the one moldings of two or more actuators shown in drawing 5 in each actuator 106. When each piezoelectric device of two or more really shown [in drawing 5] fabricated actuators 106 is circular, the actuator 106 shown in drawing 1 can be manufactured by really cutting a moldings in each actuator 106. By forming two or more actuators 106 in one, two or more actuators 106 can be efficiently manufactured to coincidence, and the handling at the time of conveyance becomes easy.

[0093] An actuator 106 has sheet metal or a diaphragm 176, a substrate 178, an elastic wave generating means or a piezoelectric device 174, a terminal formation member or the up electrode terminal 168 and a terminal formation member, or the lower electrode terminal 170. A piezoelectric device 174 contains a piezo-electric diaphragm or the piezo-electric layer 160, an upper electrode or the up electrode 164 and a bottom electrode, or the lower electrode 166. A diaphragm 176 is formed in the top face of a substrate 178, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, of the principal part of the up electrode 164, and the principal part of the lower electrode 166, the principal part of the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides.

[0094] The piezoelectric device 174 of plurality (the example of drawing 5 four pieces) is formed on the diaphragm 176. The lower electrode 166 is formed in the front face of a diaphragm 176, the piezo-electric layer 160 is formed in the front face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge of the up electrode 164 and the lower electrode 166. Four actuators 106 are cut separately, respectively and are used according to an individual.

[0095] As for drawing 6, a piezoelectric device shows some cross sections of the rectangular actuator 106.

[0096] Drawing 7 shows the cross section of the whole actuator 106 shown in drawing 6. Through tube 178a is formed in the piezoelectric device 174 of a substrate 178, and the field which counters. The closure of the through tube 178a is carried out by the diaphragm 176. A diaphragm 176 is equipped with electric insulation, such as an alumina and an oxidation zirconia, and is formed with the ingredient in which elastic deformation is possible. The piezoelectric device 174 is formed on the diaphragm 176 so that it may counter with through tube 178a. The lower electrode 166 is formed in the front face of a diaphragm 176 so that it may extend from the field of through tube 178a to the left in an one direction and drawing 7. The up electrode 164 is formed in the front face of the piezo-electric layer 160 so that it may extend in the method of the right in drawing 7 in the direction opposite to a lower electrode from the field of through tube 178a. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the top face of an auxiliary electrode 172 and the lower electrode 166, respectively. The lower electrode terminal 170 contacts the lower electrode 166 electrically, and the up

electrode terminal 168 contacts the up electrode 164 electrically through an auxiliary electrode 172, and it delivers the signal between a piezoelectric device and the exterior of an actuator 106. The up electrode terminal 168 and the lower electrode terminal 170 have the height more than the height of the piezoelectric device which doubled the electrode and the piezo-electric layer. [0097] Drawing 8 shows the manufacture approach of the actuator 106 shown in drawing 5. First, a press or laser processing is used for a green sheet 940, and through tube 940a is punched. A green sheet 940 serves as a substrate 178 after baking. A green sheet 940 is formed with ingredients, such as a ceramic. Next, the laminating of the green sheet 941 is carried out to the front face of a green sheet 940. A green sheet 941 serves as a diaphragm 176 after baking. A green sheet 941 is formed with ingredients, such as an oxidization zirconia. Next, sequential formation of a conductive layer 942, the piezo-electric layer 160, and the conductive layer 944 is carried out by approaches, such as pressure membrane printing, on the front face of a green sheet 941. A conductive layer 942 serves as the lower electrode 166 behind, and a conductive layer 944 serves as the up electrode 164 behind. Next, the formed green sheet 940, a green sheet 941, a conductive layer 942, the piezo-electric layer 160, and a conductive layer 944 are dried and calcinated. Spacing members 947 and 948 carry out bottom raising of the height of the up electrode terminal 168 and the lower electrode terminal 170, and make it higher than a piezoelectric device. Spacing members 947 and 948 carry out the laminating of printing or the green sheet, and form green sheets 940 and 941 and this ingredient. Since there are few ingredients of the up electrode terminal 168 which is noble metals, and the lower electrode terminal 170, it ends upwards by this spacing member 947,948 and thickness of the up electrode terminal 168 and the lower electrode terminal 170 can be made thin, the up electrode terminal 168 and the lower electrode terminal 170 can be printed with a sufficient precision, and it can consider as the height stabilized further.

[0098] If connection 944' with a conductive layer 944 and spacing members 947 and 948 are formed in coincidence at the time of formation of a conductive layer 942, the up electrode terminal 168 and the lower electrode terminal 170 can be formed easily, or it can fix firmly. Finally, the up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge field of a conductive layer 942 and a conductive layer 944. In case the up electrode terminal 168 and the lower electrode terminal 170 are formed, it forms so that the up electrode terminal 168 and the lower electrode terminal 170 may be electrically connected to the piezo-electric layer 160.

[0099] Drawing 9 shows the operation gestalt of further others of the ink cartridge to which this invention is applied. Drawing 9 (A) is the sectional view of the pars basilaris ossis occipitalis of the ink cartridge by this operation gestalt. The ink cartridge of this operation gestalt has through tube 1c in base 1a of a container 1 which holds ink. The pars basilaris ossis occipitalis of through tube 1c is closed by the actuator 650, and forms an ink reservoir.

[0100] Drawing 9 (B) shows the actuator 650 shown in drawing 9 (A), and the detailed cross section of through tube 1c. Drawing 9 R> 9 (C) shows the flat surface of the actuator 650 shown in drawing 9 (B), and through tube 1c. An actuator 650 has the piezoelectric device 73 fixed to the diaphragm 72 and the diaphragm 72. An actuator 650 is fixed to the base of a container 1 so that a piezoelectric device 73 may counter through tube 1c through a diaphragm 72 and a substrate 71. Elastic deformation is possible for a diaphragm 72, and it is equipped with ink-proof nature.

[0101] Depending on the amount of ink of a container 1, the amplitude and frequency of back EMF which are generated by the residual vibration of a piezoelectric device 73 and a diaphragm

72 change. Through tube 1c is formed in the location which counters an actuator 650, and the ink of the minimum constant rate is secured to through tube 1c. Therefore, the ink end of a container 1 is certainly detectable by measuring beforehand the property of vibration of the actuator 650 decided by the amount of ink secured to through tube 1c.

[0102] Drawing 10 shows other operation gestalten of through tube 1c. In each of drawing 10 (A), (B), and (C), the condition that the chart on the left does not have Ink K in through tube 1c is shown, and right-hand side drawing shows the condition that Ink K remained in through tube 1c. In the operation gestalt of drawing 9, the side face of through tube 1c is formed as a perpendicular wall. In drawing 10 (A), 1d of side faces of through tube 1c is slanting in the vertical direction, and it is expanded and opened outside. In drawing 10 (B), the level difference sections 1e and 1f are formed in the side face of through tube 1c. 1f of level difference sections which are up is larger than level difference section 1e which exists caudad. In drawing 10 (C), through tube 1c has 1g of slots which extend in the direction of the ink feed hopper 2 which is easy to discharge Ink K, i.e., the direction.

[0103] Drawing 10 (A) According to the configuration of through tube 1c shown in - (C), the amount of the ink K of an ink reservoir can be lessened. Therefore, since the oscillation characteristic of the ink and the actuator 650 at the time since M'cav explained by drawing 1 and drawing 2 can be made small as compared with M'max can be greatly changed with the case where the ink K of the amount which can be printed in a container 1 remains, an ink end can be detected more certainly.

[0104] Drawing 11 is the perspective view showing other operation gestalten of an actuator. An actuator 660 has packing 76 outside through tube 1c of the substrate which constitutes an actuator 660, or the attachment plate 78. The caulking hole 77 is formed in the periphery of an actuator 660. An actuator 660 is fixed to a container 1 with caulking through the caulking hole 77.

[0105] Drawing 12 (A) and (B) are the perspective views showing the operation gestalt of further others of an actuator. An actuator 670 is equipped with the crevice formation substrate 80 and a piezoelectric device 82 in this operation gestalt. A crevice 81 is formed in one field of the crevice formation substrate 80 of technique, such as etching, and a piezoelectric device 82 is attached in the field of another side. The pars basilaris ossis occipitalis of a crevice 81 acts as an oscillating field among the crevice formation substrates 80. Therefore, the oscillating field of an actuator 670 is specified by the periphery of a crevice 81. Moreover, an actuator 670 is similar with the structure where the substrate 178 and the diaphragm 176 were formed as one among the actuators 106 by the example of drawing 1. Therefore, in case an ink cartridge is manufactured, a production process can be shortened, and cost is reduced. An actuator 670 is size in which embedding is possible to through tube 1c prepared in the container 1. By it, a crevice 81 can act also as a cavity. In addition, like the actuator 670 by the example of drawing 12, the actuator 106 by the example of drawing 1 may be formed in through tube 1c so that embedding may be possible.

[0106] Drawing 13 is the perspective view showing the configuration which attached the actuator 106 and was really formed as a module object 100. The predetermined part of the container 1 of an ink cartridge is equipped with the module object 100. By [in liquid ink] detecting change of an acoustic impedance at least, the module object 100 is constituted so that the consumption condition of the liquid in a container 1 may be detected. The module object 100 of this operation gestalt has the liquid-container attachment section 101 for attaching an actuator 106 in a container 1. The liquid-container attachment section 101 has structure with which the

flat surface carried the cylinder section 116 which held the actuator 106 oscillated with a driving signal on the rectangular pedestal 102 mostly. Since it is constituted so that the actuator 106 of the module object 100 cannot contact from the outside when an ink cartridge is equipped with the module object 100, an actuator 106 can be protected from external contact. In addition, the radius of circle is attached, and in case the hole formed in the ink cartridge is equipped, it is easy to insert in the tip side edge of the cylinder section 116.

[0107] Drawing 14 is the exploded view showing the configuration of the module object 100 shown in drawing 13. The module object 100 contains the liquid-container attachment section 101 which consists of resin, and the piezoelectric device applied part 105 which has a plate 110 and a crevice 113. Furthermore, the module object 100 has reed wires 104a and 104b, an actuator 106, and a film 108. Preferably, a plate 110 is formed from ingredients which cannot rust easily, such as stainless steel or a stainless alloy. Opening 114 is formed in a core so that the cylinder section 116 and the pedestal 102 which are included in the liquid-container attachment section 101 can hold reed wires 104a and 104b, and a crevice 113 is formed so that an actuator 106, a film 108, and a plate 110 can be held. An actuator 106 is joined to a plate 110 through a film 108, and a plate 110 and an actuator 106 are fixed to the liquid-container attachment section 101. Therefore, reed wires 104a and 104b, an actuator 106, a film 108, and a plate 110 are attached in the liquid-container attachment section 101 as one. Reed wires 104a and 104b combine with the up electrode of an actuator 106, and a lower electrode, respectively, transmit a driving signal to a piezo-electric layer, and, on the other hand, transmit the signal of the resonance frequency which the actuator 106 detected to a recording device etc. An actuator 106 is temporarily oscillated based on the driving signal transmitted from reed wires 104a and 104b. Residual vibration of the actuator 106 is carried out after an oscillation, and it generates back EMF by the vibration. At this time, the resonance frequency corresponding to the consumption condition of the liquid in a liquid container is detectable by detecting the period of vibration of the back EMF wave. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine etc. and to paste up by thermal melting arrival. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine and to paste up by thermal melting arrival. By pasting up an actuator 106 and a plate 110 in the shape of a field with a film 108, and fixing, dispersion by the location of adhesion is lost and any parts other than the oscillating section do not vibrate. Therefore, change of the resonance frequency of the back before pasting up an actuator 106 on a plate 110 is small.

[0108] A plate 110 is a circle configuration and the opening 114 of a pedestal 102 is formed in the shape of a cylinder. The actuator 106 and the film 108 are formed in the shape of a rectangle. A reed wire 104, an actuator 106, a film 108, and a plate 110 are good also as removable to a pedestal 102. A pedestal 102, the reed wire 104, the actuator 106, the film 108, and the plate 110 are arranged to the medial axis of the module object 100 at the symmetry. furthermore, the core of a pedestal 102, an actuator 106, a film 108, and a plate 110 -- the module object 100 -- it is mostly arranged on the medial axis.

[0109] The area of the opening 114 of a pedestal 102 is formed more greatly than the area of the oscillating field of an actuator 106. The through tube 112 is formed in the location which faces the oscillating section of an actuator 106 at the core of a plate 110. As shown in drawing 1 and drawing 2, a cavity 162 is formed in an actuator 106, and both a through tube 112 and the cavity 162 form an ink reservoir. In order to lessen effect of residual ink, compared with the path of a through tube 112, the small thing of the thickness of a plate 110 is desirable. For example, as for

the depth of a through tube 112, it is desirable that it is 1/3 or less magnitude of the path. a through tube 112 is the symmetry to the medial axis of the module object 100 -- it is the configuration of a perfect circle mostly. Moreover, the area of a through tube 112 is larger than the opening area of the cavity 162 of an actuator 106. The periphery of the cross section of a through tube 112 may be a taper configuration, and a step configuration is sufficient as it. The flank of a container 1, the upper part, or a pars basilaris ossis occipitalis is equipped with the module object 100 so that a through tube 112 may turn to the inside of a container 1. If ink is consumed and the ink of the actuator 106 circumference is lost, since the resonance frequency of an actuator 106 will change a lot, at least the water of ink can detect change.

[0110] Drawing 15 is the perspective view showing other operation gestalten of a module object. As for the module object 400 of this operation gestalt, the piezoelectric device applied part 405 is formed in the liquid-container attachment section 401. As for the liquid-container attachment section 401, the cylinder-like cylinder section 403 is mostly formed for the flat surface on the pedestal 402 on Kakumaru's square. Furthermore, the piezoelectric device applied part 405 includes the tabular element 406 and crevice 413 which were stood on the cylinder section 403. An actuator 106 is arranged in the crevice 413 established in the side face of the tabular element 406. In addition, the tip of the tabular element 406 is beveled by the predetermined include angle, and in case the hole formed in the ink cartridge is equipped, it is easy to insert it in.

[0111] Drawing 16 is the decomposition perspective view showing the configuration of the module object 400 shown in drawing 15. The module object 400 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 401 and the piezoelectric device applied part 405. The liquid-container attachment section 401 has a pedestal 402 and the cylinder section 403, and the piezoelectric device applied part 405 has the tabular element 406 and a crevice 413. It is joined to a plate 410 and an actuator 106 is fixed to a crevice 413. The module object 400 has further reed wires 404a and 404b, an actuator 106, and a film 408.

[0112] According to this operation gestalt, a plate 410 is a rectangle-like and the opening 414 prepared in the tabular element 406 is formed in the shape of a rectangle. Reed wires 404a and 404b, an actuator 106, a film 408, and a plate 410 may be constituted as removable to a pedestal 402. An actuator 106, a film 408, and a plate 410 pass along the core of opening 414, and are arranged at the symmetry to the medial axis prolonged in the direction of a vertical to the flat surface of opening 414. furthermore, the core of an actuator 406, a film 408, and a plate 410 -- opening 414 -- it is mostly arranged on the medial axis.

[0113] The area of the through tube 412 prepared in the core of a plate 410 is formed more greatly than the area of opening of the cavity 162 of an actuator 106. Both the cavities 162 and through tubes 412 of an actuator 106 form an ink reservoir. The thickness of a plate 410 is small compared with the path of a through tube 412, for example, it is desirable to set it as 1/3 or less magnitude of the path of a through tube 412. a through tube 412 is the symmetry to the medial axis of the module object 400 -- it is the configuration of a perfect circle mostly. The periphery of the cross section of a through tube 412 may be a taper configuration, and a step configuration is sufficient as it. The pars basilaris ossis occipitalis of a container 1 can be equipped with the module object 400 so that a through tube 412 may be arranged inside a container 1. Since it is arranged in a container 1 so that an actuator 106 may be prolonged perpendicularly, a setup at the time of an ink end is easily changeable by changing the height which changes the height of a pedestal 402 and by which an actuator 106 is arranged in a container 1.

[0114] Drawing 17 shows the operation gestalt of further others of a module object. The module

object 500 of drawing 17 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 501 which has a pedestal 502 and the cylinder section 503. Moreover, the module object 500 has further reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510. Opening 514 is formed in a core so that the pedestal 502 included in the liquid-container attachment section 501 can hold reed wires 504a and 504b, and a crevice 513 is formed so that an actuator 106, a film 508, and a plate 510 can be held. PUAUKUHUETA 106 is fixed to the piezoelectric device applied part 505 through a plate 510. Therefore, reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510 are attached in the liquid-container attachment section 501 as one. As for the module object 500 of this operation gestalt, the cylinder section 503 with a top face slanting in the vertical direction is mostly formed for the flat surface on the pedestal on Kakumaru's square. The actuator 106 is arranged on the crevice 513 aslant prepared in the vertical direction of the top face of the cylinder section 503.

[0115] The tip of the module object 500 inclines and the inclined plane is equipped with the actuator 106. Therefore, if the pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500, an actuator 106 inclines to the vertical direction of a container 1. As for whenever [tilt-angle / of the tip of the module object 500], it is desirable to consider as for about 30 to 60 degrees in view of detectability ability.

[0116] The pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500 so that an actuator 106 may be arranged in a container 1. When the flank of a container 1 is equipped with the module object 500, it is attached in a container 1, an actuator 106 inclining so that a container 1 top, bottom, or width side may be turned to. It is desirable that it is attached in a container 1 on the other hand, an actuator 106 inclining so that the ink feed hopper side of a container 1 may be turned to when the pars basilaris ossis occipitalis of a container 1 is equipped with the module object 500.

[0117] Drawing 18 is a sectional view near the pars basilaris ossis occipitalis of the ink container when equipping a container 1 with the module object 100 shown in drawing 13. It is equipped with the module object 100 so that the side attachment wall of a container 1 may be penetrated. O ring 365 is formed in the plane of composition of the side attachment wall of a container 1, and the module object 100, and **** of the module object 100 and a container 1 is maintained at it. It is desirable to have the cylinder section which the module object 100 explained that a seal is made with an O ring by drawing 13. By the tip of the module object 100 being inserted in the interior of a container 1, the ink in a container 1 contacts an actuator 106 through the through tube 112 of a plate 110. Since the resonance frequency of the residual vibration of an actuator 106 changes with a liquid or gases, the perimeter of the oscillating section of an actuator 106 can detect the consumption condition of ink using the module object 100. Moreover, a container 1 may be equipped with the module objects 700A, 700B, 750A, and 750B shown in the module object 400 shown not only in the module object 100 but in drawing 15, the module object 500 shown in drawing 17 R> 7 or drawing 19, and drawing 20, and the mold structure 600, and the existence of ink may be detected.

[0118] Drawing 19 shows the operation gestalt of further others of the module object 100. Module object 750A of drawing 19 (A) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750A so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top

face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 385 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the through tube 385 of a container 1.

[0119] Next, the actuation of module object 750A shown in drawing 19 (A) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and residual vibration of the piezo-electric layer 160 is carried out. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave is counted, and the existence of ink can be detected by detecting the resonance frequency in the time. A container 1 is equipped only with a diaphragm 176 so that module object 750A may contact the ink in the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 , (A). Module object 750A of drawing 19 (A) becomes unnecessary [the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a and 504b shown in drawing 17 from drawing 13]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [module object 750A], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0120] Drawing 19 (B) shows the operation gestalt of further others of module object 750B. Module object 750B of drawing 19 (B) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750B so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The thin wall 380 is formed in the side attachment wall of a container 1. A container 1 is equipped only with a diaphragm 176 so that module object 750B may contact the thin wall 380 of the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 , (B). Therefore, residual vibration of the oscillating section of an actuator 106 is carried out with the thin wall 380.

[0121] Next, the actuation of module object 750B shown in drawing 19 (B) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up

electrode 164 and the lower electrode 166, and the piezo-electric layer 160 vibrates with a resonant period. Since the thin wall 380 of a container 1 is contacted, a diaphragm 176 carries out residual vibration of the oscillating section of an actuator 106 with the thin wall 380. Since the inside side of the container 1 of the thin wall 380 contacts ink, in case an actuator 106 carries out residual vibration with the thin wall 380, the resonance frequency and the amplitude of this residual vibration change with ink residues. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave can be counted, and an ink residue can be detected by detecting the resonance frequency at that time.

[0122] Module object 750B of drawing 19 (B) becomes unnecessary [the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [module object 750B], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0123] Drawing 20 (A) shows the sectional view of the ink container when equipping a container 1 with module object 700B. In this example, module object 700B is used as one of the attachment structures. The container 1 is equipped with module object 700B as the liquid-container attachment section 360 projects inside a container 1. A through tube 370 is formed in the attachment plate 350, and the oscillating section of a through tube 370 and an actuator 106 faces. Furthermore, a hole 382 is formed in the bottom wall of module object 700B, and the piezoelectric device applied part 363 is formed. As an actuator 106 closes one side of a hole 382, it is arranged. Therefore, ink contacts a diaphragm 176 through the hole 382 of the piezoelectric device applied part 363, and the through tube 370 of the attachment plate 350. Both the hole 382 of the piezoelectric device applied part 363 and the through tube 370 of the attachment plate 350 form an ink reservoir. The piezoelectric device applied part 363 and the actuator 106 are being fixed by the attachment plate 350 and the film member. The sealing structure 372 is formed in the connection of the liquid-container attachment section 360 and a container 1. The sealing structure 372 may be formed with reversible ingredients, such as synthetic resin, and may be formed with an O ring. although module object 700B of drawing 20 (A) and a container 1 are another objects -- drawing 20 (B) -- the piezoelectric device applied part of module object 700B may consist of some containers 1 like.

[0124] Module object 700B of drawing 20 (A) becomes unnecessary [the embedding to the module object of a reed wire shown in drawing 17 from drawing 13]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [module object 700B], and becomes recyclable.

[0125] In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink adhered to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. However, since the liquid-container attachment section 360 has projected module object 700B inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.

[0126] Moreover, in the example of drawing 20 (A), a container 1 is equipped with some of diaphragms 176 and attachment plates 350 so that the ink in a container 1 may be contacted. In the example of drawing 20 (A), the embedding to the module object of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13 becomes unnecessary. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [an actuator 106] and becomes recyclable.

[0127] Drawing 20 (B) shows the sectional view of an ink container as an example when equipping a container 1 with an actuator 106. In the ink cartridge by the example of drawing 20 (B), the protection member 361 is attached in the container 1 as another object in the actuator 106. Therefore, although the protection member 361 and the actuator 106 are not united as a module, they are one side, and the protection member 361 can protect them so that a user's hand cannot be touched at an actuator 106. The hole 380 prepared in the front face of an actuator 106 is arranged by the side attachment wall of a container 1. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, a diaphragm 176, and the attachment plate 350. A diaphragm 176 is formed in the top face of the attachment plate 350, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the principal part of the piezo-electric layer 160 is formed so that it may be inserted by the principal part of the up electrode 164, and the principal part of the lower electrode 166 from the upper and lower sides. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 370 is formed in the attachment plate 350. Furthermore, the hole 380 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the hole 380 of a container 1, and the through tube 370 of the attachment plate 350. Both the hole 380 of a container 1 and the through tube 370 of the attachment plate 350 form an ink reservoir. Moreover, in the example of drawing 20 (B), since the actuator 106 is protected by the protection member 361, it can protect an actuator 106 from contact outside.

[0128] In addition, it may replace with drawing 20 (A) and the attachment plate 350 in the example of (B), and the substrate 178 of drawing 1 may be used.

[0129] Drawing 20 (C) shows an operation gestalt equipped with the mold structure 600 containing an actuator 106. In this example, the mold structure 600 is used as one of the attachment structures. The mold structure 600 has an actuator 106 and the mold section 364. An actuator 106 and the mold section 364 are fabricated by one. The mold section 364 is fabricated with reversible ingredients, such as silicon resin. The mold section 364 has a reed wire 362 inside. The mold section 364 is formed so that it may have two guide pegs prolonged from an actuator 106. the mold section 364 -- the mold section 364 and a container 1 -- liquid -- since it fixes densely, the edge of two guide pegs of the mold section 364 is formed in the shape of a semi-sphere. A container 1 is equipped with the mold section 364 so that an actuator 106 may project inside a container 1, and the oscillating section of an actuator 106 contacts the ink in a container 1. The up electrode 164, the piezo-electric layer 160, and the lower electrode 166 of an actuator 106 are protected from ink by the mold section 364.

[0130] For the mold structure 600 of drawing 20 (C), since the sealing structure 372 is unnecessary between the mold section 364 and a container 1, ink is a pile to the leakage from a container 1. Moreover, since it is the gestalt in which the mold structure 600 does not project from the exterior of a container 1, an actuator 106 can be protected from contact outside. In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink was attached to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. Since the mold section 364 has projected the mold structure 600 inside the container 1, an actuator 106 does not incorrect-operate in the ink which

has hung down from the top face and side face of a container 1.

[0131] Drawing 21 shows the operation gestalt of the ink cartridge and ink jet recording device using the actuator 106 shown in drawing 1. The ink jet recording device which has two or more ink induction 182 and electrode holders 184 corresponding to each ink cartridge 180 is equipped with two or more ink cartridges 180. Two or more ink cartridges 180 hold the ink of a class different, respectively, for example, a color. Each base of two or more ink cartridges 180 is equipped with the actuator 106 which is a means to detect an acoustic impedance at least. By equipping an ink cartridge 180 with an actuator 106, the ink residue in an ink cartridge 180 is detectable.

[0132] Drawing 22 shows the detail of the head section circumference of an ink jet recording device. An ink jet recording device has the ink induction 182, an electrode holder 184, the head plate 186, and a nozzle plate 188. Two or more formation of the nozzle 190 which injects ink is carried out at the nozzle plate 188. The ink induction 182 has the air supply opening 181 and the ink inlet 183. The air supply opening 181 supplies air to an ink cartridge 180. The ink inlet 183 introduces ink from an ink cartridge 180. An ink cartridge 180 has an air induction inlet 185 and the ink feed hopper 187. An air induction inlet 185 introduces air from the air supply opening 181 of the ink induction 182. The ink feed hopper 187 supplies ink to the ink inlet 183 of the ink induction 182. When an ink cartridge 180 introduces air from the ink induction 182, supply of the ink from the ink cartridge 180 to the ink induction 182 is urged. An electrode holder 184 opens for free passage the ink supplied through the ink induction 182 from the ink cartridge 180 on the head plate 186.

[0133] Drawing 23 shows other operation gestalten of an ink cartridge 180 shown in drawing 20. Base 194a by which ink cartridge 180A of drawing 23 (A) was aslant formed in the vertical direction is equipped with the actuator 106. Inside the ink container 194 of an ink cartridge 180, the breaking-the-water wall 192 is formed in the actuator 106 of predetermined height, and the faced location from the internal base of the ink container 194. Since it is aslant equipped with the actuator 106 to the vertical direction of the ink container 194, it becomes the ***** fitness of ink.

[0134] The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles are detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192, the wave of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented.

[0135] It is equipped with the actuator 106 of ink cartridge 180B of drawing 23 (B) on the side attachment wall of the feed hopper of the ink container 194. As long as it is near the ink feed hopper 187, the side attachment wall or base of the ink container 194 may be equipped with an actuator 106. Moreover, as for an actuator 106, it is desirable that the core of the cross direction of the ink container 194 is equipped. Since ink passes the ink feed hopper 187 and is supplied outside, ink and an actuator 106 contact certainly to an ink near end time by forming an actuator 106 near the ink feed hopper 187. Therefore, an actuator 106 can detect the time of an ink near end certainly.

[0136] Furthermore, by forming an actuator 106 near the ink feed hopper 187, in case the cartridge holder on carriage is equipped with an ink container, positioning with the actuator 106 on an ink container and the contact on carriage becomes certain. In connection on an ink

container and carriage, positive association with an ink feed hopper and a supply needle is the most important for the reason. It is because its tip of a supply needle is hurt, or a damage will be given to sealing structures, such as an O ring, and ink will begin to leak, if there is a gap. In order to prevent such a trouble, the ink jet printer usually has the special structure which can do exact alignment, when mounting an ink container on carriage. Therefore, by arranging an actuator near the feed hopper, the alignment of an actuator also becomes a positive thing at coincidence. Furthermore, alignment can be more certainly carried out by equipping the core of the cross direction of the ink container 194 with an actuator 106. When an ink container carries out axial rocking a core [a crosswise center line] at the time of wearing to a holder, it is because there are few the shakes.

[0137] Drawing 24 shows the operation gestalt of further others of an ink cartridge 180. The sectional view which expanded side-attachment-wall 194b of ink cartridge 180C which showed drawing 24 (A) in the sectional view of ink cartridge 180C, and showed drawing 24 (B) to drawing 24 (A), and drawing 24 (C) are the perspective drawing from the transverse plane. Ink cartridge 180C is formed on the circuit board 610 with same semi-conductor storage means 7 and actuator 106. As shown in drawing 24 (B) and (C), the semi-conductor storage means 7 is formed above the circuit board 610, and the actuator 106 is formed under the semi-conductor storage means 7 in the same circuit board 610. Side-attachment-wall 194b is equipped with variant O ring 614 so that the perimeter of an actuator 106 may be surrounded. Two or more formation of the caulking section 616 for joining the circuit board 610 to the ink container 194 is carried out at side-attachment-wall 194b, while the oscillating field of an actuator 106 can be made to perform contacting ink by joining the circuit board 610 to the ink container 194, and pushing variant O ring 614 against the circuit board 610 by the caulking section 616 -- the exterior and the interior of an ink cartridge -- liquid -- it is kept dense.

[0138] The terminal 612 is formed in the semi-conductor storage means 7 and semi-conductor storage means 7 neighborhood. A terminal 612 delivers the signal between the semi-conductor storage means 7 and the exteriors, such as ink jet storage. The semi-conductor storage means 7 may be constituted by the rewritable semiconductor memory of EEPROM etc. On the same circuit board 610, since it is, the semi-conductor storage means 7 and an actuator 106 end like 1 time of a shipfitter, formation, now in case an actuator 106 and the semi-conductor storage means 7 are attached in ink cartridge 180C. Moreover, the routing at the time of manufacture of ink cartridge 180C and recycle is simplified. Furthermore, since the mark of components are reduced, the manufacturing cost of ink cartridge 180C can be reduced.

[0139] An actuator 106 detects the consumption condition of the ink in the ink container 194. The semi-conductor storage means 7 stores the information on ink, such as an ink residue which the actuator 106 detected. That is, the semi-conductor storage means 7 stores the information about property parameters, such as the property of the ink used in case it detects, and an ink cartridge. The semi-conductor storage means 7 stores the resonance frequency of the time of an end, at i.e., the that the ink in the ink container 194 was consumed time, as one of the property parameters, when the ink in the ink container 194 is full beforehand (i.e., when ink is filled in the ink container 194). The ink in the ink container 194 may be stored when, as for the resonance frequency of full or an end condition, an ink jet recording device is equipped with an ink container for the first time. Moreover, as for the resonance frequency of full or an end condition, the ink in the ink container 194 may be stored during manufacture of the ink container 194. Resonance frequency in case the ink in the ink container 194 is full or an end beforehand is stored in the semi-conductor storage means 7, and since dispersion at the time of detecting an ink

residue by reading the data of resonance frequency by the ink jet recording apparatus side can be amended, it is correctly detectable that the ink residue decreased to the reference value.

[0140] Drawing 25 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180D shown in drawing 25 (A) equips side-attachment-wall 194b of the ink container 194 with two or more actuators 106. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. Two or more actuators 106 set spacing in the vertical direction, and are arranged at side-attachment-wall 194b. By setting two or more actuators 106 in the vertical direction, and arranging spacing for them in it at side-attachment-wall 194b, an ink residue is gradually detectable.

[0141] Ink cartridge 180E shown in drawing 25 (B) equips side-attachment-wall 194b of the ink container 194 with the actuator 606 long in the vertical direction. Change of the ink residue in the ink container 194 is continuously detectable in the vertical direction with the long actuator 606. the die length of an actuator 606 has the die length more than one half of height in side-attachment-wall 194b -- desirable -- drawing 25 (B) -- setting -- an actuator 606 -- side-attachment-wall 194b -- it has the die length to a lower limit mostly from upper limit.

[0142] Like ink cartridge 180D shown in drawing 25 (A), ink cartridge 180F shown in drawing 25 (C) equip side-attachment-wall 194b of the ink container 194 with two or more actuators 106, set predetermined spacing to confrontation of two or more actuators 106, and are equipped with the long breaking-the-water wall 192 in the vertical direction. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles will be detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192 like this invention, ***** of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented. Moreover, the air bubbles generated because ink rocks the breaking-the-water wall 192 prevent invading into an actuator 106.

[0143] Drawing 26 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180G of drawing 26 (A) have two or more septa 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of each septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180G have two or more hold rooms 213 divided as two or more septa 212 be alike, respectively. The pars basilaris ossis occipitalis of two or more hold rooms 213 is mutually open for free passage. In each of two or more hold rooms 213, top-face 194c of the ink container 194 is equipped with the actuator 106. It is desirable to use the really fabricated actuator 106 which was shown in drawing 5 as an actuator 106 of these plurality. an actuator 106 -- top-face 194c of the hold room 213 of the ink container 194 -- it is mostly arranged in the center. The capacity of the hold room 213 is becoming small gradually as the capacity of the hold room 213 has the largest ink feed hopper 187 side and it keeps away from the ink feed hopper 187 into the ink container 194. Therefore, spacing by which an actuator 106 is arranged is narrow as the ink feed hopper 187 side is large and keeps away from the ink feed hopper 187 into the ink container 194.

[0144] Since ink is discharged from the ink feed hopper 187 and air enters from an air induction inlet 185, ink is consumed at the hold room 213 of the direction in the inner part of ink cartridge

180G from the hold room 213 by the side of the ink feed hopper 187. For example, while the ink of the hold room 213 nearest to the ink feed hopper 187 was consumed and the water level of the ink of the hold room 213 nearest to the ink feed hopper 187 has fallen, ink is filled at other hold rooms 213. If all the ink of the hold room 213 nearest to the ink feed hopper 187 is consumed, air will count from the ink feed hopper 187, and will trespass upon the 2nd hold room 213, the ink in the 2nd hold room 213 will begin to be consumed, and the water level of the ink of the 2nd hold room 213 will begin to fall. It counts from the ink supply room 187, and ink is filled at this time at the hold room 213 of the 3rd henceforth. Thus, ink is consumed in order at the hold room 213 distant from the hold room 213 near the ink feed hopper 187.

[0145] Thus, since an actuator 106 sets spacing to top-face 194c of the ink container 194 and is arranged every hold room 213 at it, as for an actuator 106, reduction of the amount of ink is gradually detectable. Furthermore, since the capacity of the hold room 213 is becoming small gradually into the ink feed hopper 187 to the hold room 213, it can detect frequency highly, so that the time interval to which an actuator 106 detects reduction of the amount of ink becomes small gradually and approaches an ink end.

[0146] Ink cartridge 180H of drawing 26 (B) have one septum 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of a septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180H have two hold rooms 213a and 213b divided by the septum 212. The pars basilaris ossis occipitalis of the hold rooms 213a and 213b is mutually open for free passage. The capacity of hold room 213a by the side of the ink feed hopper 187 is seen from the ink feed hopper 187, and is larger than the capacity of hold room 213b in the direction of back. As for the capacity of hold room 213b, it is desirable that it is smaller than the one half of the capacity of hold room 213a.

[0147] Top-face 194c of hold room 213b is equipped with an actuator 106. Furthermore, the buffer 214 which is the slot which catches the air bubbles into which it goes at the time of manufacture of ink cartridge 180H is formed in hold room 213b. In drawing 26 (B), a buffer 214 is formed as a slot which extends in the upper part from side-attachment-wall 194b of the ink container 194. Since the air bubbles which invaded in ink hold room 213b are caught, as for a buffer 214, an actuator 106 can prevent an ink end and the incorrect actuation to detect with air bubbles. Moreover, ink can be consumed to the last by applying the amendment corresponding to the consumption condition of the ink in hold room 213a grasped with the dot counter to the amount of ink after an ink near end is detected until it will be in ink and a condition completely by forming an actuator 106 in top-face 194c of hold room 213b. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0148] As for drawing 26 (C), hold room 213b of ink cartridge 180I of drawing 26 (B) is filled up with the porosity member 216. The porosity member 216 is installed so that the whole space from the top face in hold room 213b to an inferior surface of tongue may be filled. The porosity member 216 contacts an actuator 106. During the reciprocating motion the time of an ink container falling, and on carriage, air may invade in ink hold room 213b, and this may cause incorrect actuation of an actuator 106. However, if it has the porosity member 216, it can prevent catching air and air going into an actuator 106. Moreover, since the porosity member 216 holds ink, when an ink container shakes, it can prevent applying ink to an actuator 106 and an actuator 106 incorrect-detecting those without ink with those with ink. As for the porosity member 216, it is desirable to install in the hold room 213 where capacity is the smallest. Moreover, by forming

an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0149] Drawing 26 (D) shows ink cartridge 180J from which the porosity member 216 of ink cartridge 180I of drawing 26 (C) is constituted by two kinds of porosity members 216A and 216B from which an aperture differs. Porosity member 216A is arranged above porosity member 216B. The aperture of upper porosity member 216A is larger than the aperture of lower porosity member 216B. Or porosity member 216A is formed by the member with low liquid compatibility rather than porosity member 216B. Since the capillary tube force is larger than large porosity member 216A of an aperture, the ink in hold room 213b gathers for lower porous chamber portion material 216B, and the direction of small porosity member 216B of an aperture is held. Therefore, once even an actuator 106 reaches and air detects those without ink, ink will reach an actuator again and it will not detect with those with ink. Furthermore, ***** of about 106-actuator ink becomes good by ink being absorbed by porosity member 216B of a side far from an actuator 106, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0150] Drawing 27 is the sectional view showing ink cartridge 180K which are other operation gestalten of ink cartridge 180I shown in drawing 26 (C). The porosity member 216 of an ink cartridge 180 shown in drawing 27 is compressed so that the horizontal cross section of the lower part of the porosity member 216 becomes small gradually towards the direction of the base of the ink container 194, and it is designed so that an aperture may become small. In order to compress ink cartridge 180K of drawing 27 (A) so that the aperture in the direction of under the porosity member 216 becomes small, the rib is prepared in the side attachment wall. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the porosity member 216 lower part, and is held. By ink being absorbed by the porosity member 216 lower part of a side far from an actuator 106, ***** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which ink cartridge 180K top face was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.

[0151] On the other hand, in order that the horizontal cross section of the lower part of the porosity member 216 may compress ink cartridge 180L of drawing 27 (B) and drawing 27 (C) in the cross direction of the ink container 194 to become small gradually towards the base of the ink container 194, the horizontal cross section of a hold room is becoming small gradually towards the direction of the base of the ink container 194. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the lower part of the porosity member 216, and is held. By ink being absorbed by the lower part of porosity member 216B of a side far from an actuator 106, ***** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which the top face of ink cartridge 180L was

equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.

[0152] Drawing 28 shows the operation gestalt of further others of the ink cartridge which used the actuator 106. Ink cartridge 220A of drawing 28 (A) has the 1st septum 222 formed so that it might extend from the top face of ink cartridge 220A to a lower part. Since predetermined spacing is vacated between the lower limit of the 1st septum 222, and the base of ink cartridge 220A, ink can flow into the ink feed hopper 230 through the base of ink cartridge 220A. From the 1st septum 222, the 2nd septum 224 is formed in the ink feed hopper 230 side so that it may extend more nearly up than the base of ink cartridge 220A. Since predetermined spacing is vacated between the upper limit of the 2nd septum 224, and an ink cartridge 220A top face, ink can flow into the ink feed hopper 230 through the top face of ink cartridge 220A.

[0153] By the 1st septum 222, it sees from the ink feed hopper 230, and 1st hold room 225a is formed in the direction in the inner part of the 1st septum 222. On the other hand, by the 2nd septum 224, it sees from the ink feed hopper 230, and 2nd hold room 225b is formed in the near side of the 2nd septum 224. The capacity of 1st hold room 225a is larger than the capacity of 2nd hold room 225b. The capillary tube way 227 is formed by vacating only spacing which can cause capillarity between the 1st septum 222 and the 2nd septum 224. Therefore, the ink of 1st hold room 225a is brought together in the capillary tube way 227 according to the capillary tube force of the capillary tube way 227. Therefore, a gas and air bubbles can prevent mixing to 2nd hold room 225b. Moreover, the water level of the ink in 2nd hold room 225b can descend gradually stably. Since it sees from the ink feed hopper 230 and 1st hold room 225a is formed in the back from 2nd hold room 225b, after the ink of 1st hold room 225a is consumed, the ink of 2nd hold room 225b is consumed.

[0154] The side attachment wall by the side of the ink feed hopper 230 of ink cartridge 220A, i.e., the side attachment wall by the side of the ink feed hopper 230 of 2nd hold room 225b, is equipped with the actuator 106. An actuator 106 detects the consumption condition of the ink in 2nd hold room 225b. By equipping the side attachment wall of 2nd hold room 225b with an actuator 106, when near, an ink residue is stably detectable with an ink end. Furthermore, it can set up freely which time the ink residue is made into an ink end by changing the height which equips the side attachment wall of 2nd hold room 225b with an actuator 106. Since an actuator 106 is not influenced by the ink by rolling of ink cartridge 220A of rolling when ink is supplied to 2nd hold room 225b by the capillary tube way 227 from 1st hold room 225a, an actuator 106 can measure an ink residue certainly. Furthermore, since the capillary tube way 227 holds ink, ink protects flowing backwards to 1st hold room 225a from 2nd hold room 225b.

[0155] The check valve 228 is formed in the top face of ink cartridge 220A. By the check valve 228, when ink cartridge 220A rolls, it can prevent ink leaking to the ink cartridge 220A exterior. Furthermore, the evaporation from ink cartridge 220A of ink can be prevented by installing a check valve 228 in the top face of ink cartridge 220A. If the ink in ink cartridge 220A is consumed and the negative pressure in ink cartridge 220A exceeds the pressure of a check valve 228, a check valve 228 will open, air will be inhaled to ink cartridge 220A, it will close after that, and the pressure in ink cartridge 220A will be held uniformly.

[0156] Drawing 28 (C) and (D) show the cross section of the detail of a check valve 228. The check valve 228 of drawing 28 (C) has the valve 232 which has wing 232a formed of rubber. The air hole 233 with the exterior of an ink cartridge 220 counters wing 232a, and is prepared in an ink cartridge 220. An air hole 233 is opened and closed by wing 232a. If the ink in an ink cartridge 220 decreases in number and, as for a check valve 228, the negative pressure in an ink

cartridge 220 exceeds the pressure of a check valve 228, wing 232a will open inside an ink cartridge 220, and will adopt external air in an ink cartridge 220. The check valve 228 of drawing 28 (D) has the valve 232 and spring 235 which were formed of rubber. If the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, a valve 232 will press and open a spring 235, will inhale external air in an ink cartridge 220, will close a check valve 228 after that, and it will hold the negative pressure in an ink cartridge 220 uniformly.

[0157] Ink cartridge 220B of drawing 28 (B) arranges the porosity member 242 to 1st hold room 225a instead of forming a check valve 228 in ink cartridge 220A of drawing 28 (A). The porosity member 242 prevents ink leaking to the exterior of ink cartridge 220B, when ink cartridge 220B rolls, while holding the ink in ink cartridge 220B.

[0158] As mentioned above, in the carriage and the ink cartridge of another object with which carriage is equipped, although the case where an ink cartridge or carriage was equipped with an actuator 106 was described, it unites with carriage and the ink tank with which an ink jet recording apparatus is equipped with carriage may be equipped with an actuator 106.

Furthermore, the ink tank of the off-carriage method which supplies ink to carriage may be equipped with an actuator 106 through the tube of carriage and another object etc. Furthermore, the ink cartridge which the recording head and the ink container were united and was constituted exchangeable may be equipped with the actuator of this invention.

[0159] As mentioned above, although this invention was explained using the gestalt of operation, the technical range of this invention is not limited to the range given in the gestalt of the above-mentioned implementation. Various modification or amelioration can be added to the gestalt of the above-mentioned implementation. It is clear from the publication of a claim that the gestalt's which added such modification or amelioration it may be contained in the technical range of this invention.

[0160]

[Effect of the Invention] The piezoelectric device of this invention, a module object, a liquid container, and an ink cartridge can detect the residue of a liquid correctly, and its complicated seal structure is unnecessary. Furthermore, the piezoelectric device of this invention, a module object, a liquid container, and an ink cartridge can be manufactured cheaply, and its mounting nature to a liquid container is also good.

TECHNICAL FIELD

[Field of the Invention] This invention is detecting change of an acoustic impedance, and relates to the liquid container with which it had the piezoelectric device (actuator) for detecting the consumption condition of the liquid in the liquid container which holds liquids, such as ink, by detecting change of resonance frequency also especially in it. In more detail, the ink of a pressure generating room is made equivalent to print data with a pressure generating means, and it pressurizes, and is related with the piezoelectric device suitable for the ink jet recording apparatus which is made to breathe out an ink droplet and is printed from a nozzle orifice, a module object, a liquid container, and an ink cartridge.

PRIOR ART

[Description of the Prior Art] An ink jet recording device carries the ink jet recording head equipped with a pressure generating means to pressurize a pressure generating room, and the nozzle orifice which carries out the regurgitation of the pressurized ink as an ink droplet from a nozzle orifice in carriage. The ink jet recording device is constituted possible [continuation of printing], supplying the ink of an ink tank to a recording head through passage. When ink is consumed, the ink tank is constituted as a removable cartridge so that a user can exchange easily. [0003] Conventionally, there is a method of managing the time of specified quantity consumption of the ink actually being carried out etc. the approach of software integrating the amount of ink attracted by the number of regurgitation of the ink droplet in a recording head, or maintenance as a management method of ink consumption of an ink cartridge, and managing ink consumption by count, and by attaching the electrode for oil-level detection in an ink cartridge. [0004] However, the approach of software integrating the number of regurgitation and the amount of ink of an ink droplet, and managing ink consumption on count has the problem that an error arises according to the printing gestalt in a user side etc., and gross errors arise at the time of re-wearing of the same cartridge. Moreover, there was also a problem that the error which the pressure in an ink cartridge and the viscosity of ink change with the elapsed time after opening of height with a going too far room temperature or an ink cartridge etc., and cannot be disregarded between the ink consumption on count and actual consumption will arise by the operating environment. Since the method of on the other hand managing the time of ink being consumed with an electrode can detect the amount of real of ink, it can manage an ink residue with high dependability. However, since it depends for detection of the oil level of ink on the conductivity of ink, the class of detectable ink is limited and there is a problem which the seal structure of an electrode complicates. Moreover, since noble metals good [usually] conductivity and high were used as an ingredient of an electrode, there were corrosion resistance and a problem that the manufacturing cost of an ink cartridge increased. Furthermore, since it was necessary to equip with two electrodes, the production process increased and there was also a problem that a manufacturing cost will increase as a result.

EFFECT OF THE INVENTION

[Effect of the Invention] The piezoelectric device of this invention, a module object, a liquid container, and an ink cartridge can detect the residue of a liquid correctly, and its complicated seal structure is unnecessary. Furthermore, the piezoelectric device of this invention, a module object, a liquid container, and an ink cartridge can be manufactured cheaply, and its mounting nature to a liquid container is also good.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Then, this invention aims at offering the piezoelectric device and module object which can solve the above-mentioned technical problem, which could detect the ink residue correctly and made complicated seal structure unnecessary and with which a liquid container is equipped. This purpose is attained by the combination of the description given in the independent term in a claim. Moreover, a subordination term specifies the further advantageous example of this invention.

MEANS

[Means for Solving the Problem] That is, a liquid container is equipped with the piezoelectric device in the 1st gestalt of this invention, it is the piezoelectric device which detects the consumption condition of the liquid in a liquid container, said piezoelectric device has the oscillating section which vibration generates according to deformation of a piezo electric crystal component, and, as for the oscillating section, it is desirable to have a symmetrical configuration to the core.

[0007] Moreover, as for the oscillating section of a piezoelectric device, it is desirable to have an almost circular configuration. Furthermore, the up electrode prepared in the top face of a piezo-electric layer and a piezo-electric layer, the lower electrode prepared in the inferior surface of tongue of a piezo-electric layer, and a top face touch a lower electrode, a piezoelectric device is equipped with the diaphragm with which at the bottom [a part of] contacts the liquid in a liquid container, and, as for the oscillating section, it is desirable that some of a piezo-electric layer, up electrodes, lower electrodes, and each diaphragms [at least] are included. Furthermore, it is desirable that each principal piece of a piezo-electric layer, an up electrode, and a lower electrode is the oscillating section and the configuration where a concentric circle is almost circular.

[0008] Moreover, as for a piezoelectric device, it is desirable to have a cavity in contact with a liquid in the location where a top face touches the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, an inferior surface of tongue is further equipped with the substrate in contact with the liquid in a liquid container, and a substrate faces the oscillating section. As for a cavity, it is desirable the oscillating section and that it is the circle configuration of a concentric circle mostly. Moreover, it is desirable that deformation of the diaphragm by residual vibration is larger than deformation of a substrate. The knot of vibration of the oscillating section may be located near the periphery section of a cavity. As for a piezoelectric device, it is desirable that a top face touches the inferior-surface-of-tongue side in contact with the liquid of a diaphragm, have further the attachment member an inferior surface of tongue turns [member] to the inside of a liquid container, and an attachment member has opening in the core of the oscillating section. Furthermore, it is desirable that it is the liquid container with which it was equipped with the above-mentioned piezoelectric device.

[0009] As for the module object in the 2nd gestalt of this invention, it is desirable to have the attachment structure united with the above-mentioned piezoelectric device and the piezoelectric device for attaching a piezoelectric device in a liquid container.

[0010] The core of the oscillating section may be arranged on the center line of the overhang section including the overhang section which the attachment structure juts out inside a liquid container. Furthermore, the overhang section may be a cylindrical shape. You may have further

the terminal which gives a driving signal to the up electrode and lower electrode of a piezoelectric device. Moreover, it is desirable that it is the liquid container with which it was equipped with the above-mentioned module object. Moreover, you may be the ink cartridge which holds the ink supplied to an ink jet recording apparatus in the above-mentioned liquid container.

[0011] In addition, the outline of the above-mentioned invention is not what enumerated all the required descriptions of this invention, and the subcombination of these characterizing group can also be invented.

[0012]

[Embodiment of the Invention] Hereafter, this invention is explained to a detail through the gestalt of implementation of invention. Not all the combination of the description of the following operation gestalten that do not limit invention concerning a claim and are explained in the operation gestalt is necessarily indispensable for the solution means of invention.

[0013] The underlying concept of this invention is using an oscillating phenomenon, and is detecting the condition (the existence of the liquid in a liquid container, the amount of a liquid, the water level of a liquid, the class of liquid, and the presentation of a liquid being included) of the liquid in a liquid container. Some approaches can be considered as detection of the condition of the liquid in the liquid container using a concrete oscillating phenomenon. For example, an elastic wave generating means generates an elastic wave to the interior of a liquid container, and there is a method of detecting the medium in a liquid container and change of the condition by receiving the reflected wave reflected with an oil level or the wall which counters. Moreover, there is also the approach of detecting change of an acoustic impedance apart from this from the oscillation characteristic of the vibrating body. As an approach of using change of an acoustic impedance By vibrating the oscillating section of the piezoelectric device or actuator which has a piezoelectric device, and measuring back EMF produced by the residual vibration which remains in the oscillating section after that The approach of detecting change of an acoustic impedance by detecting resonance frequency or the back EMF wave amplitude, The impedance characteristic or admittance property of a liquid is measured with impedance analyzers, such as a measurement machine, for example, a propagation circuit etc., and there is the approach of measuring change by the frequency of the current value when giving a current value, an electrical-potential-difference value change, or vibration to a liquid or an electrical-potential-difference value. Hereafter, the detail of the principle of operation of a piezoelectric device or an actuator is explained.

[0014] Drawing 1 and drawing 2 show the detail and equal circuit of an actuator 106 which are 1 operation gestalt of a piezoelectric device. An actuator here is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container. It is used for the approach of detecting change of an acoustic impedance at least and detecting the consumption condition of the liquid in a liquid container because resonance frequency detects by residual vibration especially. Drawing 1 (A) is the expansion top view of an actuator 106. Drawing 1 (B) shows the B-B cross section of an actuator 106. Drawing 1 (C) shows the C-C cross section of an actuator 106. Furthermore, drawing 2 (A) and drawing 2 (B) show the equal circuit of an actuator 106. Moreover, drawing 2 (C) and drawing 2 (D) show the circumference containing the actuator 106 when ink is filled in the ink cartridge, respectively, and its equal circuit, and drawing 2 (E) and drawing 2 (F) show the circumference containing the actuator 106 in case there is no ink into an ink cartridge, respectively, and its equal circuit.

[0015] The substrate 178 with which an actuator 106 has the opening 161 of a circle

configuration in the center mostly, The diaphragm 176 arranged in one field (henceforth a front face) of a substrate 178 so that opening 161 may be covered, The piezo-electric layer 160 arranged at the front-face side of a diaphragm 176, and the up electrode 164 and the lower electrode 166 which inserts the piezo-electric layer 160 from both, It has the auxiliary electrode 172 which is arranged between the up electrode terminal 168 electrically combined with the up electrode 164, the lower electrode terminal 170 electrically combined with the lower electrode 166, and the up electrode 164 and the up electrode terminal 168, and combines both electrically. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 have a circular part as each principal part. Each circular part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device.

[0016] A diaphragm 176 is formed in the front face of a substrate 178 so that opening 161 may be covered. A cavity 162 is formed of the opening 161 of a diaphragm 176, the facing part, and the opening 161 of the front face of a substrate 178. With the piezoelectric device of a substrate 178, the field (henceforth a rear face) of the opposite side faces the liquid-container side, and the cavity 162 is constituted so that a liquid may be contacted. even if a liquid enters in a cavity 162, a liquid does not leak to the front-face side of a substrate 178 -- as -- a diaphragm 176 -- a substrate 178 -- receiving -- liquid -- it is attached densely.

[0017] The front face of a diaphragm 176, i.e., a liquid container, is located in the field of the opposite side, and the lower electrode 166 is attached so that the core of a circular part and the core of opening 161 which are the principal part of the lower electrode 166 may be mostly in agreement. In addition, it is set up so that the area of the circular part of the lower electrode 166 may become smaller than the area of opening 161. On the other hand, the piezo-electric layer 160 is formed in the front-face side of the lower electrode 166 so that the core of the circular part and the core of opening 161 may be mostly in agreement. The area of the circular part of the piezo-electric layer 160 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of opening 161.

[0018] On the other hand, it is formed in the front-face side of the piezo-electric layer 160 so that the core of a circular part and the core of opening 161 that the up electrode 164 is the principal part may be mostly in agreement. The area of the circular part of the up electrode 164 is set up so that it may become larger than the area of the circular part of the lower electrode 166 smaller than the area of the circular parts of opening 161 and the piezo-electric layer 160.

[0019] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164.

Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0020] Therefore, the principal part of the piezo-electric layer 160 has structure inserted and crowded from a front-face and rear-face side, respectively by the principal part of the up electrode 164, and the principal part of the lower electrode 166, and can carry out the deformation drive of the piezo-electric layer 160 effectively. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms the piezoelectric device in an actuator 106. The piezoelectric device is in contact with the diaphragm 176 as mentioned above. Moreover, opening 161 has the largest area among the circular parts of the circular parts of the circular part of the up electrode 164, and the piezo-electric layer 160, and the lower electrode 166, and opening 161. The oscillating field which actually vibrates among diaphragms 176 according to this structure is determined by opening 161. Moreover, since the circular parts of the circular part of the up electrode 164 and the piezo-electric layer 160 and the circular part of the lower electrode 166 have an area smaller than opening 161, a diaphragm 176 becomes easier to vibrate. Furthermore, the circular part of the lower electrode 166 is smaller among the circular part of the lower electrode 166 electrically connected with the piezo-electric layer 160, and the circular part of the up electrode 164. Therefore, the circular part of the lower terminal 166 determines the part which generates the piezo-electric effect among the piezo-electric layers 160.

[0021] The core of the circular parts of the piezo-electric layer 160 which forms a piezoelectric device, the up electrode 164, and the lower electrode 166 corresponds with the core of opening 161 mostly. moreover, the core of the opening 161 of a circle configuration of determining the vibrating part of a diaphragm 176 -- an actuator 106 -- it is mostly prepared in the core. Therefore, the core of the oscillating section of an actuator 106 is mostly in agreement with the core of an actuator. Furthermore, since the principal piece of a piezoelectric device and the vibrating part of a diaphragm 176 have a circular configuration, the oscillating section of an actuator 106 is a symmetrical configuration to the core of an actuator 106.

[0022] Since the oscillating section is a symmetrical configuration, it can be prevented from exciting an unnecessary vibration produced from the asymmetry of structure to the core of an actuator 106. Therefore, the detection precision of resonance frequency improves. Furthermore, to an actuator core, since the oscillating section is a symmetrical configuration, it is easy to manufacture it and it can make small dispersion in the configuration for every piezoelectric device. Therefore, dispersion in the resonance frequency for every piezoelectric device becomes small. Moreover, since the oscillating section is an isotropic configuration, it is hard to be influenced of dispersion in immobilization in the case of adhesion. A liquid container is pasted equally. Therefore, the mounting nature to the liquid container of an actuator 106 is good.

[0023] Furthermore, since the vibrating part of a diaphragm 176 has a circular configuration, in the resonance mode of the residual vibration of the piezo-electric layer 160, the resonance mode of a low degree, for example, primary, becomes dominant, and a single peak appears. Therefore, since a peak and a noise are clearly distinguishable, resonance frequency is clearly detectable. Moreover, by enlarging area of the vibrating part of the diaphragm 176 of a circular configuration, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and can improve the precision of detection of resonance frequency further.

[0024] The variation rate by vibration of a diaphragm 176 is farther [than the variation rate by vibration of a substrate 178] large. Compliance is small, namely, an actuator 106 has the two-

layer structure of the substrate 178 which is hard to displace by vibration, and the diaphragm 176 which compliance is large, namely, is easy to displace by vibration. According to this two-layer structure, since the variation rate of the diaphragm 176 by vibration can be enlarged certainly being fixed to a liquid container by the substrate 178, the difference of the back EMF wave amplitude and the amplitude of the resonance frequency by the existence of a liquid becomes large, and the precision of detection of resonance frequency can be improved. Furthermore, since the compliance of a diaphragm 176 is large, attenuation of vibration becomes small and the precision of detection of resonance frequency can be improved. Moreover, the knot of vibration of an actuator 106 is located near the edge of the periphery section 161 of a cavity 162, i.e., opening.

[0025] The up electrode terminal 168 is formed in the front-face side of a diaphragm 176 so that it may connect with the up electrode 164 electrically through an auxiliary electrode 172. On the other hand, the lower electrode terminal 170 is formed in the front-face side of a diaphragm 176 so that it may connect with the lower electrode 166 electrically. Since the up electrode 164 is formed in the front-face side of the piezo-electric layer 160, it needs to have a level difference equal to the sum of the thickness of the piezo-electric layer 160, and the thickness of the lower electrode 166 while connecting with the up electrode terminal 168. The connection condition of the up electrode 164 and the up electrode terminal 168 becomes weak, and forming this level difference only with the up electrode 164 has risk of cutting, even if it is difficult and possible in a loan. Then, the up electrode 164 and the up electrode terminal 168 are connected, using an auxiliary electrode 172 as an auxiliary member. It becomes possible for the piezo-electric layer 160 and the up electrode 164 to serve as structure supported by the auxiliary electrode 172, and to be able to obtain a desired mechanical strength, and to ensure connection between the up electrode 164 and the up electrode terminal 168 by doing in this way.

[0026] In addition, the oscillating field which faces a piezoelectric device and the piezoelectric device of the diaphragms 176 is the oscillating section which actually vibrates in an actuator 106. Moreover, as for the member contained in an actuator 106, being formed in one is desirable by being calcinated mutually. By forming an actuator 106 in one, the handling of an actuator 106 becomes easy. Furthermore, an oscillation characteristic improves by raising the reinforcement of a substrate 178. That is, by raising the reinforcement of a substrate 178, only the oscillating section of an actuator 106 vibrates and any parts other than the oscillating section do not vibrate among actuators 106. Moreover, in order for any parts other than the oscillating section of an actuator 106 not to vibrate, it can attain by making the piezoelectric device of an actuator 106 thinly and small, and making a diaphragm 176 thin to raising the reinforcement of a substrate 178.

[0027] It is desirable to use the lead loess piezoelectric film which does not use PZT (PZT), the PZT lanthanum (PLZT), or lead as an ingredient of the piezo-electric layer 160, and it is desirable to use a zirconia or an alumina as an ingredient of a substrate 178. Moreover, it is desirable to use the same ingredient as a substrate 178 for a diaphragm 176. Metals, such as the ingredient which has conductivity, for example, gold, silver, copper, platinum, aluminum, and nickel, can be used for the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170.

[0028] The actuator 106 constituted as mentioned above is applicable to the container which holds a liquid. For example, the container which held the penetrant remover for washing the ink cartridge and ink tank which are used for an ink jet recording apparatus, or a recording head can be equipped.

[0029] The predetermined location of a liquid container is equipped with the actuator 106 shown in [drawing 1](#) and [drawing 2](#) so that the liquid held in a liquid container in a cavity 162 may be contacted. When the liquid is fully held in the liquid container, the inside of a cavity 162 and its outside are filled by the liquid. On the other hand, if the liquid of a liquid container is consumed and an oil level descends below to the stowed position of an actuator, a liquid does not exist in a cavity 162, or a liquid remains only in a cavity 162, and it will be in the condition that a gas exists on the outside. An actuator 106 detects the difference of an acoustic impedance as it is [originating in change of this condition, and] few. By it, an actuator 106 can detect whether it is in the condition that the liquid is fully held in the liquid container, or it is in the condition that a certain liquid more than fixed was consumed. Furthermore, an actuator 106 can also detect the class of liquid in a liquid container.

[0030] Here explains the principle of the oil-level detection by the actuator.

[0031] In order to detect change of the acoustic impedance of a medium, the impedance characteristic or admittance property of a medium is measured. A propagation circuit can be used when measuring an impedance characteristic or an admittance property. A propagation circuit impresses a fixed electrical potential difference to a medium, and measures the current which changes a frequency and flows to a medium. Or a propagation circuit supplies a fixed current to a medium, and measures the electrical potential difference which changes a frequency and is impressed to a medium. The current value or electrical-potential-difference value change measured by the propagation circuit shows change of an acoustic impedance. Moreover, change of the frequency f_m from which a current value or an electrical-potential-difference value serves as the maximum or the minimum also shows change of an acoustic impedance.

[0032] Apart from the above-mentioned approach, an actuator can detect change of the acoustic impedance of a liquid using change of only resonance frequency. A piezoelectric device can be used, when using the approach of detecting resonance frequency by measuring back EMF produced by the residual vibration which remains in the oscillating section, as an approach of using change of the acoustic impedance of a liquid after the oscillating section of an actuator vibrates. A piezoelectric device is a component which generates back EMF by the residual vibration which remains in the oscillating section of an actuator, and the magnitude of back EMF changes with the amplitude of the oscillating section of an actuator. Therefore, it is easy to carry out detection, so that the amplitude of the oscillating section of an actuator is large. Moreover, the period from which the magnitude of back EMF changes with the frequencies of the residual vibration in the oscillating section of an actuator changes. Therefore, the frequency of the oscillating section of an actuator is equivalent to the frequency of back EMF. Here, resonance frequency says the frequency in the resonance state with the medium which touches the oscillating section and the oscillating section of an actuator.

[0033] In order to obtain resonance frequency f_s , the Fourier transform of the wave acquired by the back EMF measurement in case the oscillating section and a medium are the resonance state is carried out. Since vibration of an actuator is accompanied not by deformation of only an one direction but by various deformation, such as a deflection and expanding, it has various frequencies including resonance frequency f_s . Therefore, the Fourier transform of the wave of back EMF in case a piezoelectric device and a medium are the resonance state is carried out, and resonance frequency f_s is judged by specifying the most dominant frequency component.

[0034] The admittance of a medium of a frequency f_m is a frequency in case the maximum or an impedance is the minimum. If it is resonance frequency f_s , a frequency f_m will produce few errors to resonance frequency f_s by dielectric loss or a mechanical loss of a medium etc.

However, since time and effort is taken, generally deriving resonance frequency f_s from the frequency f_m surveyed replaces with and uses a frequency f_m for resonance frequency. Here, an actuator 106 can detect an acoustic impedance at least in inputting the output of an actuator 106 into a propagation circuit.

[0035] It is proved to be the approach of measuring resonance frequency f_s by experiment by measuring the approach of measuring the impedance characteristic or admittance property of a medium, and measuring a frequency f_m , and back EMF produced by residual vibration vibration in the oscillating section of an actuator that there is almost no difference in the resonance frequency specified as be alike.

[0036] The oscillating field of an actuator 106 is a part which constitutes the cavity 162 determined by opening 161 among diaphragms 176. When the liquid is fully held in the liquid container, in a cavity 162, a liquid is filled and an oscillating field contacts the liquid in a liquid container. On the other hand, when there is no enough liquid into a liquid container, an oscillating field does not contact a liquid in contact with the liquid which remained in the cavity in a liquid container, but contacts a gas or a vacuum.

[0037] A cavity 162 is formed in the actuator 106 of this invention, and it can design so that the liquid in a liquid container may remain in the oscillating field of an actuator 106 by it. The reason is as follows.

[0038] Although there is an oil level of the liquid in a liquid container caudad depending on [stowed position / of an actuator] whenever [installation location / to the liquid container of an actuator /, or setting-angle], a liquid may adhere to the oscillating field of an actuator. When the actuator has detected the existence of a liquid only by the existence of the liquid in an oscillating field, the liquid adhering to the oscillating field of an actuator bars exact detection of the existence of a liquid. for example, the time of the condition that there is an oil level caudad rather than the stowed position of an actuator -- both-way migration of carriage etc. -- a liquid container -- rocking -- a liquid -- a wave -- inside, if a drop adheres to an oscillating field, an actuator will make a judgment which if liquids of enough are in a liquid container mistook. Then, malfunction of an actuator can be prevented, even if it is the case where a liquid is remained conversely there and an oil level is [a liquid container rocks and] choppy by preparing positively the cavity designed so that the existence of a liquid might be detected correctly. Thus, malfunction can be prevented by using the actuator which has a cavity.

[0039] Moreover, as shown in drawing 2 (E), there is no liquid into a liquid container and let the case where the liquid in a liquid container remains in the cavity 162 of an actuator 106 be the threshold of the existence of a liquid. That is, there is no liquid around a cavity 162 and it judges that he has no ink when there are few liquids in a cavity than this threshold, a liquid is around a cavity 162, and when there are more liquids than this threshold, it is judged as those with ink. For example, when the side attachment wall of a liquid container is equipped with an actuator 106, the case where the liquid in a liquid container is below the stowed position of an actuator is judged to have no ink, and the case where the liquid in a liquid container is above the stowed position of an actuator is judged to be those with ink. Thus, even if it is a time of the ink in a cavity drying and ink being lost by setting up a threshold, it judges that he has no ink, and since a threshold is not exceeded even if ink adheres to a cavity again in the shake of carriage etc. at the place whose ink in a cavity was lost, it can be judged that he has no ink.

[0040] Here, the actuation and the principle which detect the condition of the liquid in a liquid container from the resonance frequency of the medium and the oscillating section of an actuator 106 by measurement of back EMF are explained, referring to drawing 1 and drawing 2. In an

actuator 106, an electrical potential difference is impressed to the up electrode 164 and the lower electrode 166 through the up electrode terminal 168 and the lower electrode terminal 170, respectively. Electric field arise into the part pinched by the up electrode 164 and the lower electrode 166 among the piezo-electric layers 160. The piezo-electric layer 160 deforms by the electric field. When the piezo-electric layer 160 deforms, the oscillating field of the diaphragms 176 oscillates flexurally. After the piezo-electric layer 160 deforms, flexural oscillation remains in the oscillating section of an actuator 106 for the time being.

[0041] Residual vibration is the free vibration of the oscillating section of an actuator 106, and a medium. Therefore, by making into pulse shape or a square wave the electrical potential difference impressed to the piezo-electric layer 160, after impressing an electrical potential difference, the resonance state of the oscillating section and a medium can be acquired easily. Residual vibration also deforms the piezo-electric layer 160 in order to vibrate the oscillating section of an actuator 106. Therefore, the piezo-electric layer 160 generates back EMF. The back EMF is detected through the up electrode 164, the lower electrode 166, the up electrode terminal 168, and the lower electrode terminal 170. Since resonance frequency can be specified, the condition of the liquid in a liquid container is detectable with detected back EMF.

[0042] Generally, it is resonance frequency f_s . $f_s = 1 / (2 * \pi * (M * C_{act})^{1/2})$ (formula 1)

It is come out and expressed. Here, M is the sum of the inertia M_{act} of the oscillating section, and addition inertia M' . C_{act} is the compliance of the oscillating section.

[0043] Drawing 1 (C) is the sectional view of the actuator 106 when ink does not remain in a cavity in this example. Drawing 2 (A) and drawing 2 (B) are the oscillating section of the actuator 106 when ink does not remain in a cavity, and the equal circuit of a cavity 162.

[0044] Mact should ** the product of the thickness of the oscillating section, and the consistency of the oscillating section in the area of the oscillating section, and should show it further to a detail at drawing 2 (A). $M_{act} = M_{pzt} + M_{electrode1} + M_{electrode2} + M_{vib}$ (formula 2)

It is expressed. Here, M_{pzt} ** the product of the thickness of the piezo-electric layer 160 and the consistency of the piezo-electric layer 160 in the oscillating section in the area of the piezo-electric layer 160. $M_{electrode1}$ ** the product of the thickness of the up electrode 164 and the consistency of the up electrode 164 in the oscillating section in the area of the up electrode 164. $M_{electrode2}$ ** the product of the thickness of the lower electrode 166 and the consistency of the lower electrode 166 in the oscillating section in the area of the lower electrode 166. M_{vib} ** the product of the thickness of a diaphragm 176 and the consistency of a diaphragm 176 in the oscillating section in the area of the oscillating field of a diaphragm 176. However, in this example, although each area of the oscillating field of the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176 has the above size relation, a minute thing is desirable [the difference of a mutual area], so that M_{act} can be computed from the thickness, the consistency, and area as the whole oscillating section. Moreover, as for parts other than the circular part which are those principal parts, in this example, it is desirable in the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 that it is so minute that it can ignore to the principal part. Therefore, in an actuator 106, M_{act} is the sum of each inertia of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176. Moreover, Compliance C_{act} is the compliance of the part formed of the up electrode 164, the lower electrode 166, the piezo-electric layer 160, and the oscillating field of the diaphragms 176.

[0045] In addition, although drawing 2 (A), drawing 2 (B), drawing 2 (D), and drawing 2 (F) show the oscillating section of an actuator 106, and the equal circuit of a cavity 162, in these

equal circuits, Cact shows the compliance of the oscillating section of an actuator 106. Cpzt, Electrode1 and Electrode2, and Cvib show the compliance of the piezo-electric layer 160 in the oscillating section, the up electrode 164, the lower electrode 166, and a diaphragm 176, respectively. Cact is expressed with the following formulas 3.

[0046]

$$1/Cact = (1/Cpzt) + (1/Electrode1) + (1/Electrode2) + (1/Cvib) \quad (\text{formula 3})$$

From a formula 2 and a formula 3, drawing 2 (A) can also be expressed like drawing 2 (B).

[0047] Compliance Cact expresses the volume which can receive a medium according to the deformation when putting a pressure on the unit area of the oscillating section. Moreover, Compliance Cact may say that it expresses the ease of carrying out of deformation.

[0048] A liquid is fully held in a liquid container and drawing 2 (C) shows the sectional view of the actuator 106 in case the liquid is filled around the oscillating field of an actuator 106. A liquid is fully held in a liquid container and M'max of drawing 2 (C) expresses the maximum of an addition inertance in case the liquid is filled around the oscillating field of an actuator 106. M'max is [0049].

$$M'max = (\pi \cdot \rho \cdot (2 \cdot k^3)) \cdot (2 \cdot (2 \cdot k \cdot a)^3 / (3 \cdot \pi)) / (\pi \cdot a^2)^2 \quad (\text{formula 4})$$

(a is [the consistency of a medium and k of the radius of the oscillating section and rho] the wave numbers.)

[0050] It is come out and expressed. In addition, a formula 4 is materialized when the radius a of the oscillating field of an actuator 106 is circular. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. As shown in a formula 4, M'max changes with the radius a of the oscillating section, and the consistencies rho of a medium a lot.

[0051] The wave number k is $k = 2 \cdot \pi \cdot \text{fact} / c$. (formula 5)

(fact is the resonance frequency of the oscillating section when the liquid is not touching.) c is the rate of the sound which spreads the inside of a medium.

[0052] It is come out and expressed.

[0053] A liquid is fully held in a liquid container and drawing 2 (D) shows the oscillating section of the actuator 106 in the case of being drawing 2 (C) with which the liquid is filled around the oscillating field of an actuator 106, and the equal circuit of a cavity 162.

[0054] Although the liquid of a liquid container is consumed and drawing 2 (E) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the sectional view of the actuator 106 when the liquid remains is shown. A formula 4 is a formula showing the greatest inertance M'max determined from the consistency rho of ink etc., when the liquid is filled by the liquid container. It is [0055] when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum on the other hand, the liquid in a liquid container having been consumed and a liquid remaining in a cavity 162. $M' = \rho \cdot t / S$ (formula 6)

It can express. t is the thickness of the medium in connection with vibration. S is the area of the oscillating field of an actuator 106. It is $S = \pi \cdot a^2$ when the radius a of this oscillating field is circular. Therefore, addition inertance M' follows a formula 4, when a liquid is fully held in a liquid container and the liquid is filled around the oscillating field of an actuator 106. On the other hand, a liquid is consumed, and a formula 6 is followed when the liquid around the oscillating field of an actuator 106 becomes a gas or a vacuum, a liquid remaining in a cavity 162.

[0056] Here, although the liquid of a liquid container is consumed and there is no liquid around the oscillating field of an actuator 106 like drawing 2 (E), addition inertance M' when the liquid

remains in the cavity 162 of an actuator 106 is made into M'_{cav} for convenience, and it distinguishes from addition inductance M'_{max} in case the liquid is filled around the oscillating field of an actuator 106.

[0057] Although the liquid of a liquid container is consumed and drawing 2 (F) does not have a liquid around the oscillating field of an actuator 106, in the cavity 162 of an actuator 106, the oscillating section of the actuator 106 in the case of being drawing 2 (E) in which the liquid remains, and the equal circuit of a cavity 162 are shown.

[0058] Here, the parameters related to the condition of a medium are the consistency ρ of a medium, and thickness t of a medium in a formula 6. When the liquid is fully held in the liquid container, a liquid contacts the oscillating section of an actuator 106, when the liquid is not fully held in the liquid container, a liquid remains inside a cavity or a gas or a vacuum contacts the oscillating section of an actuator 106. The surrounding liquid of an actuator 106 is consumed, if the addition inductance in the process which shifts to M'_{cav} of drawing 2 (E) from M'_{max} of drawing 2 (C) is made into M'_{var} , since thickness t of the consistency ρ of a medium and a medium changes, addition inductance M'_{var} will change and resonance frequency f_s will also change with the hold conditions of the liquid in a liquid container. Therefore, the existence of the liquid in a liquid container is detectable by specifying resonance frequency f_s . When M'_{cav} is expressed using a formula 6, depth d of a cavity is substituted for t of a formula 6, and it is [0059].

$M'_{cav} = \rho \cdot d / S$ (formula 7)

It becomes.

[0060] Moreover, since a consistency ρ changes with differences in a presentation even if a medium is a liquid with which classes differ mutually, addition inductance M' changes and resonance frequency f_s also changes. Therefore, the class of liquid is detectable by specifying resonance frequency f_s . In addition, when either ink or air contacts and it is not intermingled in the oscillating section of an actuator 106, the difference of M' can be detected even if it calculates by the formula 4.

[0061] Drawing 3 (A) is a graph which shows relation with the resonance frequency f_s of the amount of the ink in an ink tank, ink, and the oscillating section. Here, ink is explained as one example of a liquid. An axis of ordinate shows resonance frequency f_s , and an axis of abscissa shows the amount of ink. When an ink presentation is fixed, resonance frequency f_s rises with the fall of an ink residue.

[0062] When ink is fully held in an ink container and ink is filled around the oscillating field of an actuator 106, the maximum addition inductance M'_{max} serves as a value expressed to a formula 4. On the other hand, ink is consumed, and when ink is not filled around the oscillating field of an actuator 106, a liquid remaining in a cavity 162, addition inductance M'_{var} is computed by the formula 6 based on thickness t of a medium. t in a formula 6 can also detect the process in which ink is gradually consumed by being small in d (referring to drawing 1 (B)) of the cavity 162 of an actuator 106, namely, making a substrate 178 thin enough since it is the thickness of the medium in connection with vibration (refer to drawing 2 (C)). Here, t ink considers as the thickness of the ink in connection with vibration, and sets t ink-max to t ink in M'_{max} . For example, an actuator 106 is arranged almost horizontally to the oil level of ink on the base of an ink cartridge. If ink is consumed and the oil level of ink reaches below the height of t from an actuator 106, M'_{var} will change with formulas 6 gradually and resonance frequency f_s will change with formulas 1 gradually. Therefore, as long as the oil level of ink is within the limits of t , as for an actuator 106, the consumption condition of ink is detectable gradually.

[0063] Moreover, according to the location of the oil level by consumption of ink, S in a formula 6 changes by making the oscillating field of an actuator 106 greatly or long, and arranging perpendicularly. Therefore, an actuator 106 can also detect the process in which ink is consumed gradually. For example, an actuator 106 is arranged almost perpendicularly to the oil level of ink on the side attachment wall of an ink cartridge. If ink is consumed and the oil level of ink arrives at the oscillating field of an actuator 106, since addition inductance M' will decrease with the fall of water level, resonance frequency f_s increases gradually by the formula 1. Therefore, as for an actuator 106, the oil level of ink can detect the consumption condition of ink gradually, as long as it is within the limits of path 2a (refer to drawing 2 (C)) of a cavity 162.

[0064] The curve X of drawing 3 (A) expresses relation with the resonance frequency f_s of the amount of the ink held in the ink tank the case where the cavity 162 of an actuator 106 is made shallow enough, and at the time of making the oscillating field of an actuator 106 greatly enough or long, ink, and the oscillating section. While the amount of the ink in an ink tank decreases, he can understand signs that the resonance frequency f_s of ink and the oscillating section changes gradually.

[0065] The case where the process in which ink is consumed gradually is detectable in a detail is a case where both the liquids and gases from which a consistency differs mutually exist, and it is concerned with vibration, in the circumference of the oscillating field of an actuator 106 more. While liquids decrease in number, a gas increases the medium on the circumference of an oscillating field of an actuator 106, and in connection with vibration, as ink is consumed gradually. For example, it is the case where an actuator 106 is horizontally arranged to the oil level of ink, and when tink is smaller than tink-max, the medium in connection with vibration of an actuator 106 contains both ink and a gas. Therefore, it is [0066] when the condition of having become below M'max of a formula 4 when it was the area S of the oscillating field of an actuator 106 is expressed with the additional mass of ink and a gas.

$M' = M'_{air} + M'_{ink} = \rho_{air} \cdot t_{air} / S + \rho_{ink} \cdot t_{ink} / S$ (formula 8)

It becomes. Here, M'_{air} is the inductance of air and M'_{ink} is the inductance of ink. ρ_{air} is the consistency of air and ρ_{ink} is the consistency of ink. t_{air} is the thickness of the air in connection with vibration, and t_{ink} is the thickness of the ink in connection with vibration. When the actuator 106 is arranged almost horizontally to the oil level of ink as liquids decrease in number among the media in connection with the vibration in the circumference of an oscillating field of an actuator 106 and a gas increases, t_{air} increases and t_{ink} decreases. By it, M' var decreases gradually and resonance frequency increases gradually. Therefore, the amount of the ink which remains in an ink tank, or the consumption of ink is detectable. In addition, in a formula 7, it is the formula of only the consistency of a liquid because the case of being so small that the consistency of air being disregarded is assumed to the consistency of a liquid.

[0067] When the actuator 106 is arranged almost perpendicularly to the oil level of ink, the media in connection with vibration of an actuator 106 are considered to be the field of only ink, and the equal circuit (not shown) of juxtaposition of the medium in connection with vibration of an actuator 106 with a gaseous field among the oscillating fields of an actuator 106. It is [0068], when the medium in connection with vibration of an actuator 106 sets area of the field of only ink to Sink and the medium in connection with vibration of an actuator 106 sets area of a gaseous field to Sair.

$1/M' = 1/M'_{air} + 1/M'_{ink} = S_{air} / (\rho_{air} \cdot t_{air}) + S_{ink} / (\rho_{ink} \cdot t_{ink})$ (formula 9)

It becomes.

[0069] In addition, a formula 9 is applied when ink is not held at the cavity of an actuator 106.

About the case where ink is held at the cavity of an actuator 106, it is calculable with a formula 7, a formula 8, and a formula 9.

[0070] On the other hand, the oil level of ink will detect an upper location or a bottom location from the stowed position of an actuator rather than a substrate 178 is thick, namely, depth d of a cavity 162 is deep, and it detects the process in which ink decreases in number gradually in practice, when d uses an actuator with a very small oscillating field as compared with the case of being comparatively close to thickness $t_{ink-max}$ of a medium, and the height of a liquid container. When it puts in another way, the existence of the ink in the oscillating field of an actuator will be detected. For example, the curve Y of drawing 3 (A) shows relation with the resonance frequency f_s of the amount of the ink in the ink tank in the case of a small circular oscillating field, ink, and the oscillating section. Between the amounts Q of ink before and after the oil level of the ink in an ink tank passes through the stowed position of an actuator, signs that the resonance frequency f_s of ink and the oscillating section is changing violently are shown. From this, it is detectable in an ink tank whether ink is carrying out specified quantity survival.

[0071] A diaphragm 176 is contacting a liquid and directly, and since the method of detecting the existence of a liquid using an actuator 106 detects the existence of ink, compared with the approach of calculating the consumption of ink with software, its detection precision is high. Furthermore, although the approach conductivity detects the existence of ink is influenced according to the attaching position to a liquid container, and the class of ink using an electrode, the approach of detecting the existence of a liquid using an actuator 106 is not influenced according to the attaching position to a liquid container, and the class of ink. Furthermore, since the both sides of detection of the existence of a liquid can be considered as an oscillation using the single actuator 106, the number of the sensors attached in a liquid container as compared with the approach of carrying out oscillation and detection of the existence of a liquid using a different sensor can be decreased. Therefore, a liquid container can be manufactured cheaply. Furthermore, it can be [sound / which an actuator 106 generates working] quiet by setting the oscillation frequency of the piezo-electric layer 160 as a non-audible field.

[0072] Drawing 3 (B) shows relation with the resonance frequency f_s of the consistency of the ink in the curve Y of drawing 3 (A), ink, and the oscillating section. Ink is mentioned as an example of a liquid. Since an addition inertance will become large if an ink consistency becomes high as shown in drawing 3 (B), resonance frequency f_s falls. That is, resonance frequency f_s changes with classes of ink. Therefore, in case it is re-filled up with ink by measuring resonance frequency f_s , it can check whether the ink in which consistencies differed is mixed.

[0073] That is, the ink tank which holds the ink in which classes differ mutually is discriminable.

[0074] Then, even if the liquid in a liquid container is the state of the sky, the conditions which can detect correctly the condition of a liquid when setting up the size and the configuration of a cavity so that a liquid may remain in the cavity 162 of an actuator 106 are explained in full detail. If the condition of a liquid can be detected when the liquid is filled in the cavity 162, an actuator 106 can detect the condition of a liquid, even if it is the case where the liquid is not filled in the cavity 162.

[0075] Resonance frequency f_s is a function of Inertance M . Inertance M is the sum of the inertance M_{act} of the oscillating section, and addition inertance M' . Here, addition inertance M' is related to the condition of a liquid. Addition inertance M' is an amount which shows that the mass of the oscillating section is increasing seemingly according to an operation of the medium near the oscillating section. That is, the increment of the mass of the oscillating section by absorbing a medium seemingly by vibration of the oscillating section is said.

[0076] Therefore, when M'_{cav} is larger than M'_{max} in a formula 4, all the media absorbed seemingly are liquids which remain in a cavity 162. Therefore, it is the same as the condition that the liquid is filled in the liquid container. In this case, since M' does not change, resonance frequency f_s does not change, either. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.

[0077] On the other hand, when M'_{cav} is smaller than M'_{max} in a formula 4, the medium absorbed seemingly is the gas or vacuum in the liquid which remains in a cavity 162, and a liquid container. Since M' changes unlike the condition that the liquid is filled in the liquid container at this time, resonance frequency f_s changes. Therefore, an actuator 106 can detect the condition of the liquid in a liquid container.

[0078] That is, the liquid in a liquid container is the state of the sky, and when a liquid remains in the cavity 162 of an actuator 106, the conditions on which an actuator 106 can detect the condition of a liquid correctly are that M'_{cav} is smaller than M'_{max} . In addition, condition $M'_{max} > M'_{cav}$ to which an actuator 106 can detect the condition of a liquid correctly is not concerned with the configuration of a cavity 162.

[0079] Here, M'_{cav} is the capacity of a cavity 162, and the mass of the liquid of an almost equal capacity. Therefore, an actuator 106 can express the conditions which can detect the condition of a liquid correctly as conditions for the capacity of a cavity 162 from the inequality of $M'_{max} > M'_{cav}$. For example, it is [0080], when the radius of the opening 161 of the cavity 162 of a circle configuration is set to a and the depth of a cavity 162 is set to d . $M'_{max} > \rho \cdot d \cdot \pi a^2$ (formula 10)

It comes out. It is [0081] when a formula 10 is developed. $a/d > 3 \cdot \pi / 8$ (formula 11)

The conditions to say are searched for. In addition, when the configuration of a cavity 162 is circular, a formula 10 and a formula 11 are restricted and are materialized. If πa^2 in a formula 10 is calculated by replacing it with the area using the formula of M'_{max} when not being circular, the relation between dimensions, such as width of face of a cavity and die length, and the depth can be drawn.

[0082] Therefore, if it is the actuator 106 which has the cavity 162 which are the radius a of the opening 161 which fills a formula 11, and depth d of a cavity 162, even if the liquid in a liquid container is the state of the sky and it is the case where a liquid remains in a cavity 162, the condition of a liquid can be detected, without incorrect-operating.

[0083] It can be said that the approach of measuring back EMF generated in an actuator 106 by residual vibration has detected change of an acoustic impedance at least since addition inductance M' also influences an acoustic-impedance property.

[0084] Moreover, according to this example, back EMF which an actuator 106 generates vibration and generates in an actuator 106 by subsequent residual vibration is measured. However, it is not necessarily required for the oscillating section of an actuator 106 to give vibration to a liquid by its vibration by driver voltage. That is, even if the oscillating section does not oscillate itself, the piezo-electric layer 160 bends and deforms by vibrating with the liquid of a certain range in contact with it. This residual vibration makes the piezo-electric layer 160 generate the back EMF electrical potential difference, and transmits that back EMF electrical potential difference to the up electrode 164 and the lower electrode 166. The condition of a medium may be detected by using this phenomenon. For example, it may set to an ink jet recording apparatus, and the condition of an ink tank or the ink of the interior may be detected using vibration around the oscillating section of the actuator generated by vibration by the reciprocating motion of the carriage by the scan of the print head at the time of printing.

[0085] Drawing 4 (A) And drawing 4 (B) shows the wave of the residual vibration of an actuator 106 after vibrating an actuator 106, and the measuring method of residual vibration. the ink in the stowed position level of the actuator 106 in an ink cartridge -- the upper and lower sides of water level are detectable with frequency change of the residual vibration after an actuator 106 oscillates, and change of the amplitude. Drawing 4 (A) And in drawing 4 (B), an axis of ordinate shows the electrical potential difference of back EMF generated by the residual vibration of an actuator 106, and an axis of abscissa shows time amount. By the residual vibration of an actuator 106, it is drawing 4 R> 4 (A). And as shown in drawing 4 (B), the wave of the analog signal of an electrical potential difference occurs. Next, an analog signal is changed into the digital numeric value corresponding to the frequency of a signal.

[0086] In the example shown in drawing 4 (A) and drawing 4 (B), the existence of ink is detected by measuring the time amount which four pulses to 8 pulse eye produce from 4 pulse eye of an analog signal.

[0087] More, in a detail, after an actuator 106 oscillates, the count which crosses the predetermined reference voltage set up beforehand from a low-battery side to a high-voltage side is counted. The between from four counts to eight counts is set to High for a digital signal, and the time amount from four counts to eight counts is measured by the predetermined clock pulse.

[0088] Drawing 4 (A) is a wave in case a liquid ink side is in a high order rather than the stowed position level of an actuator 106. On the other hand, drawing 4 (B) is a wave in case there is no ink in the stowed position level of an actuator 106. When drawing 4 R> 4 (A) is compared with drawing 4 (B), in drawing 4 (A), a ***** understands the time amount from four counts to eight counts from drawing 4 (B). A paraphrase changes the time amount from four counts to eight counts by the existence of ink. The consumption condition of ink is detectable using a difference of this time amount. After vibration of an actuator 106 is stabilized, it counts for beginning measurement from 4 count eye of an analog wave. What it was presupposed that it is from 4 count eye is a mere example, and may count from the count of arbitration. Here, the signal from 4 count eye to 8 count eye is detected, and the time amount from 4 count eye to 8 count eye is measured by the predetermined clock pulse. It asks for resonance frequency by it. As for a clock pulse, it is desirable that it is the pulse of a clock equal to the clock for controlling the semiconductor memory attached in an ink cartridge. In addition, there is no need of measuring the time amount to 8 count eye, and it may be counted to the count of arbitration. In drawing 4, although the time amount from 4 count eye to 8 count eye is measured, according to the circuitry which detects a frequency, the time amount in a different counting interval may be detected.

[0089] For example, when fluctuation of the amplitude of a peak is small, in order the quality of ink is stable, and to gather the rate of detection, you may ask for resonance frequency by detecting the time amount from 4 count eye to 6 count eye. Moreover, the quality of ink is unstable, and when fluctuation of the amplitude of a pulse is large, in order to detect residual vibration correctly, the time amount from 4 count eye to 12 count eye may be detected.

[0090] Moreover, the wave number of the voltage waveform of back EMF within a predetermined period may be counted as other examples (not shown). It can ask for resonance frequency also by this approach. More, in a detail, after an actuator 106 oscillates, only a predetermined period sets a digital signal to High, and the count which crosses predetermined reference voltage from a low-battery side to a high-voltage side is counted. The existence of ink is detectable by measuring the number of counts.

[0091] Furthermore, the back EMF wave amplitudes differ by the case where there are not a case

where ink is filled in the ink cartridge, and ink into an ink cartridge so that drawing 4 (A) and drawing 4 (B) may be compared and understood. Therefore, the consumption condition of the ink in an ink cartridge may be detected also by measuring the back EMF wave amplitude, without asking for resonance frequency. Top-most vertices and drawing 4 (B) of the back EMF wave [detail] of drawing 4 R> 4 (A) more Reference voltage is set up between the top-most vertices of the back EMF wave. When a digital signal is set to High at predetermined time and the back EMF wave crosses reference voltage after the actuator 106 oscillated, it is judged that there is no ink. When the back EMF wave does not cross reference voltage, it is judged that there is ink.

[0092] Drawing 5 shows the manufacture approach of an actuator 106. Two or more actuators 106 (the example of drawing 5 four pieces) are formed in one. The actuator 106 shown in drawing 6 is manufactured by cutting the one moldings of two or more actuators shown in drawing 5 in each actuator 106. When each piezoelectric device of two or more really shown [in drawing 5] fabricated actuators 106 is circular, the actuator 106 shown in drawing 1 can be manufactured by really cutting a moldings in each actuator 106. By forming two or more actuators 106 in one, two or more actuators 106 can be efficiently manufactured to coincidence, and the handling at the time of conveyance becomes easy.

[0093] An actuator 106 has sheet metal or a diaphragm 176, a substrate 178, an elastic wave generating means or a piezoelectric device 174, a terminal formation member or the up electrode terminal 168 and a terminal formation member, or the lower electrode terminal 170. A piezoelectric device 174 contains a piezo-electric diaphragm or the piezo-electric layer 160, an upper electrode or the up electrode 164 and a bottom electrode, or the lower electrode 166. A diaphragm 176 is formed in the top face of a substrate 178, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, of the principal part of the up electrode 164, and the principal part of the lower electrode 166, the principal part of the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides.

[0094] The piezoelectric device 174 of plurality (the example of drawing 5 four pieces) is formed on the diaphragm 176. The lower electrode 166 is formed in the front face of a diaphragm 176, the piezo-electric layer 160 is formed in the front face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge of the up electrode 164 and the lower electrode 166. Four actuators 106 are cut separately, respectively and are used according to an individual.

[0095] As for drawing 6 , a piezoelectric device shows some cross sections of the rectangular actuator 106.

[0096] Drawing 7 shows the cross section of the whole actuator 106 shown in drawing 6 . Through tube 178a is formed in the piezoelectric device 174 of a substrate 178, and the field which counters. The closure of the through tube 178a is carried out by the diaphragm 176. A diaphragm 176 is equipped with electric insulation, such as an alumina and an oxidation zirconia, and is formed with the ingredient in which elastic deformation is possible. The piezoelectric device 174 is formed on the diaphragm 176 so that it may counter with through tube 178a. The lower electrode 166 is formed in the front face of a diaphragm 176 so that it may extend from the field of through tube 178a to the left in an one direction and drawing 7 . The up electrode 164 is formed in the front face of the piezo-electric layer 160 so that it may extend in

the method of the right in drawing 7 in the direction opposite to a lower electrode from the field of through tube 178a. The up electrode terminal 168 and the lower electrode terminal 170 are formed in the top face of an auxiliary electrode 172 and the lower electrode 166, respectively. The lower electrode terminal 170 contacts the lower electrode 166 electrically, and the up electrode terminal 168 contacts the up electrode 164 electrically through an auxiliary electrode 172, and it delivers the signal between a piezoelectric device and the exterior of an actuator 106. The up electrode terminal 168 and the lower electrode terminal 170 have the height more than the height of the piezoelectric device which doubled the electrode and the piezo-electric layer.

[0097] Drawing 8 shows the manufacture approach of the actuator 106 shown in drawing 5. First, a press or laser processing is used for a green sheet 940, and through tube 940a is punched. A green sheet 940 serves as a substrate 178 after baking. A green sheet 940 is formed with ingredients, such as a ceramic. Next, the laminating of the green sheet 941 is carried out to the front face of a green sheet 940. A green sheet 941 serves as a diaphragm 176 after baking. A green sheet 941 is formed with ingredients, such as an oxidization zirconia. Next, sequential formation of a conductive layer 942, the piezo-electric layer 160, and the conductive layer 944 is carried out by approaches, such as pressure membrane printing, on the front face of a green sheet 941. A conductive layer 942 serves as the lower electrode 166 behind, and a conductive layer 944 serves as the up electrode 164 behind. Next, the formed green sheet 940, a green sheet 941, a conductive layer 942, the piezo-electric layer 160, and a conductive layer 944 are dried and calcinated. Spacing members 947 and 948 carry out bottom raising of the height of the up electrode terminal 168 and the lower electrode terminal 170, and make it higher than a piezoelectric device. Spacing members 947 and 948 carry out the laminating of printing or the green sheet, and form green sheets 940 and 941 and this ingredient. Since there are few ingredients of the up electrode terminal 168 which is noble metals, and the lower electrode terminal 170, it ends upwards by this spacing member 947, 948 and thickness of the up electrode terminal 168 and the lower electrode terminal 170 can be made thin, the up electrode terminal 168 and the lower electrode terminal 170 can be printed with a sufficient precision, and it can consider as the height stabilized further.

[0098] If connection 944' with a conductive layer 944 and spacing members 947 and 948 are formed in coincidence at the time of formation of a conductive layer 942, the up electrode terminal 168 and the lower electrode terminal 170 can be formed easily, or it can fix firmly. Finally, the up electrode terminal 168 and the lower electrode terminal 170 are formed in the edge field of a conductive layer 942 and a conductive layer 944. In case the up electrode terminal 168 and the lower electrode terminal 170 are formed, it forms so that the up electrode terminal 168 and the lower electrode terminal 170 may be electrically connected to the piezo-electric layer 160.

[0099] Drawing 9 shows the operation gestalt of further others of the ink cartridge to which this invention is applied. Drawing 9 (A) is the sectional view of the pars basilaris ossis occipitalis of the ink cartridge by this operation gestalt. The ink cartridge of this operation gestalt has through tube 1c in base 1a of a container 1 which holds ink. The pars basilaris ossis occipitalis of through tube 1c is closed by the actuator 650, and forms an ink reservoir.

[0100] Drawing 9 (B) shows the actuator 650 shown in drawing 9 (A), and the detailed cross section of through tube 1c. Drawing 9 R> 9 (C) shows the flat surface of the actuator 650 shown in drawing 9 (B), and through tube 1c. An actuator 650 has the piezoelectric device 73 fixed to the diaphragm 72 and the diaphragm 72. An actuator 650 is fixed to the base of a container 1 so that a piezoelectric device 73 may counter through tube 1c through a diaphragm 72 and a

substrate 71. Elastic deformation is possible for a diaphragm 72, and it is equipped with ink-proof nature.

[0101] Depending on the amount of ink of a container 1, the amplitude and frequency of back EMF which are generated by the residual vibration of a piezoelectric device 73 and a diaphragm 72 change. Through tube 1c is formed in the location which counters an actuator 650, and the ink of the minimum constant rate is secured to through tube 1c. Therefore, the ink end of a container 1 is certainly detectable by measuring beforehand the property of vibration of the actuator 650 decided by the amount of ink secured to through tube 1c.

[0102] Drawing 10 shows other operation gestalten of through tube 1c. In each of drawing 10 (A), (B), and (C), the condition that the chart on the left does not have Ink K in through tube 1c is shown, and right-hand side drawing shows the condition that Ink K remained in through tube 1c. In the operation gestalt of drawing 9, the side face of through tube 1c is formed as a perpendicular wall. In drawing 10 (A), 1d of side faces of through tube 1c is slanting in the vertical direction, and it is expanded and opened outside. In drawing 10 (B), the level difference sections 1e and 1f are formed in the side face of through tube 1c. 1f of level difference sections which are up is larger than level difference section 1e which exists caudad. In drawing 10 (C), through tube 1c has 1g of slots which extend in the direction of the ink feed hopper 2 which is easy to discharge Ink K, i.e., the direction.

[0103] Drawing 10 (A) According to the configuration of through tube 1c shown in - (C), the amount of the ink K of an ink reservoir can be lessened. Therefore, since the oscillation characteristic of the ink and the actuator 650 at the time since M'cav explained by drawing 1 and drawing 2 can be made small as compared with M'max can be greatly changed with the case where the ink K of the amount which can be printed in a container 1 remains, an ink end can be detected more certainly.

[0104] Drawing 11 is the perspective view showing other operation gestalten of an actuator. An actuator 660 has packing 76 outside through tube 1c of the substrate which constitutes an actuator 660, or the attachment plate 78. The caulking hole 77 is formed in the periphery of an actuator 660. An actuator 660 is fixed to a container 1 with caulking through the caulking hole 77.

[0105] Drawing 12 (A) and (B) are the perspective views showing the operation gestalt of further others of an actuator. An actuator 670 is equipped with the crevice formation substrate 80 and a piezoelectric device 82 in this operation gestalt. A crevice 81 is formed in one field of the crevice formation substrate 80 of technique, such as etching, and a piezoelectric device 82 is attached in the field of another side. The pars basilaris ossis occipitalis of a crevice 81 acts as an oscillating field among the crevice formation substrates 80. Therefore, the oscillating field of an actuator 670 is specified by the periphery of a crevice 81. Moreover, an actuator 670 is similar with the structure where the substrate 178 and the diaphragm 176 were formed as one among the actuators 106 by the example of drawing 1. Therefore, in case an ink cartridge is manufactured, a production process can be shortened, and cost is reduced. An actuator 670 is size in which embedding is possible to through tube 1c prepared in the container 1. By it, a crevice 81 can act also as a cavity. In addition, like the actuator 670 by the example of drawing 12, the actuator 106 by the example of drawing 1 may be formed in through tube 1c so that embedding may be possible.

[0106] Drawing 13 is the perspective view showing the configuration which attached the actuator 106 and was really formed as a module object 100. The predetermined part of the container 1 of an ink cartridge is equipped with the module object 100. By [in liquid ink]

detecting change of an acoustic impedance at least, the module object 100 is constituted so that the consumption condition of the liquid in a container 1 may be detected. The module object 100 of this operation gestalt has the liquid-container attachment section 101 for attaching an actuator 106 in a container 1. The liquid-container attachment section 101 has structure with which the flat surface carried the cylinder section 116 which held the actuator 106 oscillated with a driving signal on the rectangular pedestal 102 mostly. Since it is constituted so that the actuator 106 of the module object 100 cannot contact from the outside when an ink cartridge is equipped with the module object 100, an actuator 106 can be protected from external contact. In addition, the radius of circle is attached, and in case the hole formed in the ink cartridge is equipped, it is easy to insert in the tip side edge of the cylinder section 116.

[0107] Drawing 14 is the exploded view showing the configuration of the module object 100 shown in drawing 13. The module object 100 contains the liquid-container attachment section 101 which consists of resin, and the piezoelectric device applied part 105 which has a plate 110 and a crevice 113. Furthermore, the module object 100 has reed wires 104a and 104b, an actuator 106, and a film 108. Preferably, a plate 110 is formed from ingredients which cannot rust easily, such as stainless steel or a stainless alloy. Opening 114 is formed in a core so that the cylinder section 116 and the pedestal 102 which are included in the liquid-container attachment section 101 can hold reed wires 104a and 104b, and a crevice 113 is formed so that an actuator 106, a film 108, and a plate 110 can be held. An actuator 106 is joined to a plate 110 through a film 108, and a plate 110 and an actuator 106 are fixed to the liquid-container attachment section 101. Therefore, reed wires 104a and 104b, an actuator 106, a film 108, and a plate 110 are attached in the liquid-container attachment section 101 as one. Reed wires 104a and 104b combine with the up electrode of an actuator 106, and a lower electrode, respectively, transmit a driving signal to a piezo-electric layer, and, on the other hand, transmit the signal of the resonance frequency which the actuator 106 detected to a recording device etc. An actuator 106 is temporarily oscillated based on the driving signal transmitted from reed wires 104a and 104b. Residual vibration of the actuator 106 is carried out after an oscillation, and it generates back EMF by the vibration. At this time, the resonance frequency corresponding to the consumption condition of the liquid in a liquid container is detectable by detecting the period of vibration of the back EMF wave. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine etc. and to paste up by thermal melting arrival. a film 108 -- an actuator 106 and a plate 110 -- pasting up -- an actuator -- liquid -- it is made dense. As for a film 108, it is desirable to form with polyolefine and to paste up by thermal melting arrival. By pasting up an actuator 106 and a plate 110 in the shape of a field with a film 108, and fixing, dispersion by the location of adhesion is lost and any parts other than the oscillating section do not vibrate. Therefore, change of the resonance frequency of the back before pasting up an actuator 106 on a plate 110 is small.

[0108] A plate 110 is a circle configuration and the opening 114 of a pedestal 102 is formed in the shape of a cylinder. The actuator 106 and the film 108 are formed in the shape of a rectangle. A reed wire 104, an actuator 106, a film 108, and a plate 110 are good also as removable to a pedestal 102. A pedestal 102, the reed wire 104, the actuator 106, the film 108, and the plate 110 are arranged to the medial axis of the module object 100 at the symmetry. furthermore, the core of a pedestal 102, an actuator 106, a film 108, and a plate 110 -- the module object 100 -- it is mostly arranged on the medial axis.

[0109] The area of the opening 114 of a pedestal 102 is formed more greatly than the area of the oscillating field of an actuator 106. The through tube 112 is formed in the location which faces

the oscillating section of an actuator 106 at the core of a plate 110. As shown in drawing 1 and drawing 2, a cavity 162 is formed in an actuator 106, and both a through tube 112 and the cavity 162 form an ink reservoir. In order to lessen effect of residual ink, compared with the path of a through tube 112, the small thing of the thickness of a plate 110 is desirable. For example, as for the depth of a through tube 112, it is desirable that it is 1/3 or less magnitude of the path. a through tube 112 is the symmetry to the medial axis of the module object 100 -- it is the configuration of a perfect circle mostly. Moreover, the area of a through tube 112 is larger than the opening area of the cavity 162 of an actuator 106. The periphery of the cross section of a through tube 112 may be a taper configuration, and a step configuration is sufficient as it. The flank of a container 1, the upper part, or a pars basilaris ossis occipitalis is equipped with the module object 100 so that a through tube 112 may turn to the inside of a container 1. If ink is consumed and the ink of the actuator 106 circumference is lost, since the resonance frequency of an actuator 106 will change a lot, at least the water of ink can detect change.

[0110] Drawing 15 is the perspective view showing other operation gestalten of a module object. As for the module object 400 of this operation gestalt, the piezoelectric device applied part 405 is formed in the liquid-container attachment section 401. As for the liquid-container attachment section 401, the cylinder-like cylinder section 403 is mostly formed for the flat surface on the pedestal 402 on Kakumaru's square. Furthermore, the piezoelectric device applied part 405 includes the tabular element 406 and crevice 413 which were stood on the cylinder section 403. An actuator 106 is arranged in the crevice 413 established in the side face of the tabular element 406. In addition, the tip of the tabular element 406 is beveled by the predetermined include angle, and in case the hole formed in the ink cartridge is equipped, it is easy to insert it in.

[0111] Drawing 16 is the decomposition perspective view showing the configuration of the module object 400 shown in drawing 15. The module object 400 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 401 and the piezoelectric device applied part 405. The liquid-container attachment section 401 has a pedestal 402 and the cylinder section 403, and the piezoelectric device applied part 405 has the tabular element 406 and a crevice 413. It is joined to a plate 410 and an actuator 106 is fixed to a crevice 413. The module object 400 has further reed wires 404a and 404b, an actuator 106, and a film 408.

[0112] According to this operation gestalt, a plate 410 is a rectangle-like and the opening 414 prepared in the tabular element 406 is formed in the shape of a rectangle. Reed wires 404a and 404b, an actuator 106, a film 408, and a plate 410 may be constituted as removable to a pedestal 402. An actuator 106, a film 408, and a plate 410 pass along the core of opening 414, and are arranged at the symmetry to the medial axis prolonged in the direction of a vertical to the flat surface of opening 414. furthermore, the core of an actuator 406, a film 408, and a plate 410 -- opening 414 -- it is mostly arranged on the medial axis.

[0113] The area of the through tube 412 prepared in the core of a plate 410 is formed more greatly than the area of opening of the cavity 162 of an actuator 106. Both the cavities 162 and through tubes 412 of an actuator 106 form an ink reservoir. The thickness of a plate 410 is small compared with the path of a through tube 412, for example, it is desirable to set it as 1/3 or less magnitude of the path of a through tube 412. a through tube 412 is the symmetry to the medial axis of the module object 400 -- it is the configuration of a perfect circle mostly. The periphery of the cross section of a through tube 412 may be a taper configuration, and a step configuration is sufficient as it. The pars basilaris ossis occipitalis of a container 1 can be equipped with the module object 400 so that a through tube 412 may be arranged inside a container 1. Since it is

arranged in a container 1 so that an actuator 106 may be prolonged perpendicularly, a setup at the time of an ink end is easily changeable by changing the height which changes the height of a pedestal 402 and by which an actuator 106 is arranged in a container 1.

[0114] Drawing 17 shows the operation gestalt of further others of a module object. The module object 500 of drawing 17 as well as the module object 100 shown in drawing 13 contains the liquid-container attachment section 501 which has a pedestal 502 and the cylinder section 503. Moreover, the module object 500 has further reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510. Opening 514 is formed in a core so that the pedestal 502 included in the liquid-container attachment section 501 can hold reed wires 504a and 504b, and a crevice 513 is formed so that an actuator 106, a film 508, and a plate 510 can be held. PUAUKCHUETA 106 is fixed to the piezoelectric device applied part 505 through a plate 510. Therefore, reed wires 504a and 504b, an actuator 106, a film 508, and a plate 510 are attached in the liquid-container attachment section 501 as one. As for the module object 500 of this operation gestalt, the cylinder section 503 with a top face slanting in the vertical direction is mostly formed for the flat surface on the pedestal on Kakumaru's square. The actuator 106 is arranged on the crevice 513 aslant prepared in the vertical direction of the top face of the cylinder section 503.

[0115] The tip of the module object 500 inclines and the inclined plane is equipped with the actuator 106. Therefore, if the pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500, an actuator 106 inclines to the vertical direction of a container 1. As for whenever [tilt-angle / of the tip of the module object 500], it is desirable to consider as for about 30 to 60 degrees in view of detectability ability.

[0116] The pars basilaris ossis occipitalis or flank of a container 1 is equipped with the module object 500 so that an actuator 106 may be arranged in a container 1. When the flank of a container 1 is equipped with the module object 500, it is attached in a container 1, an actuator 106 inclining so that a container 1 top, bottom, or width side may be turned to. It is desirable that it is attached in a container 1 on the other hand, an actuator 106 inclining so that the ink feed hopper side of a container 1 may be turned to when the pars basilaris ossis occipitalis of a container 1 is equipped with the module object 500.

[0117] Drawing 18 is a sectional view near the pars basilaris ossis occipitalis of the ink container when equipping a container 1 with the module object 100 shown in drawing 13. It is equipped with the module object 100 so that the side attachment wall of a container 1 may be penetrated. O ring 365 is formed in the plane of composition of the side attachment wall of a container 1, and the module object 100, and **** of the module object 100 and a container 1 is maintained at it. It is desirable to have the cylinder section which the module object 100 explained that a seal is made with an O ring by drawing 13. By the tip of the module object 100 being inserted in the interior of a container 1, the ink in a container 1 contacts an actuator 106 through the through tube 112 of a plate 110. Since the resonance frequency of the residual vibration of an actuator 106 changes with a liquid or gases, the perimeter of the oscillating section of an actuator 106 can detect the consumption condition of ink using the module object 100. Moreover, a container 1 may be equipped with the module objects 700A, 700B, 750A, and 750B shown in the module object 400 shown not only in the module object 100 but in drawing 15, the module object 500 shown in drawing 17 R> 7 or drawing 19, and drawing 20, and the mold structure 600, and the existence of ink may be detected.

[0118] Drawing 19 shows the operation gestalt of further others of the module object 100. Module object 750A of drawing 19 (A) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750A so that a front face may turn into an inside of the side

attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 385 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the through tube 385 of a container 1.

[0119] Next, the actuation of module object 750A shown in drawing 19 (A) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and residual vibration of the piezo-electric layer 160 is carried out. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave is counted, and the existence of ink can be detected by detecting the resonance frequency in the time. A container 1 is equipped only with a diaphragm 176 so that module object 750A may contact the ink in the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 (A). Module object 750A of drawing 19 (A) becomes unnecessary [the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a and 504b shown in drawing 17 from drawing 13]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [module object 750A], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside.

[0120] Drawing 19 (B) shows the operation gestalt of further others of module object 750B. Module object 750B of drawing 19 (B) has an actuator 106 and a pedestal 360. The container 1 is equipped with module object 750B so that a front face may turn into an inside of the side attachment wall of a container 1, and the same field. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, and a diaphragm 176. The lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the piezo-electric layer 160 is formed so that it may be inserted from the upper and lower sides with the up electrode 164 and the lower electrode 166. The piezo-electric layer 160, the up electrode 164, and the lower electrode 166 form a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The thin wall 380 is formed in the side attachment wall of a container 1. A container 1 is equipped only with a diaphragm 176 so that module object 750B may contact the thin wall 380 of the ink container 1 in the field where an actuator 106 is opposite to the piezoelectric-device side of the oscillating section of an actuator 106, i.e., drawing 19 (B). Therefore, residual vibration of the oscillating section of an actuator 106 is carried out with the thin wall 380.

[0121] Next, the actuation of module object 750B shown in drawing 19 (B) is explained. The up electrode 164 and the lower electrode 166 transmit a driving signal to the piezo-electric layer 160, and transmit the signal of the resonance frequency which the piezo-electric layer 160 detected to a recording device. It oscillates with the driving signal transmitted with the up electrode 164 and the lower electrode 166, and the piezo-electric layer 160 vibrates with a resonant period. Since the thin wall 380 of a container 1 is contacted, a diaphragm 176 carries out residual vibration of the oscillating section of an actuator 106 with the thin wall 380. Since the inside side of the container 1 of the thin wall 380 contacts ink, in case an actuator 106 carries out residual vibration with the thin wall 380, the resonance frequency and the amplitude of this residual vibration change with ink residues. The piezo-electric layer 160 generates back EMF by this residual vibration. The period of vibration of the back EMF wave can be counted, and an ink residue can be detected by detecting the resonance frequency at that time.

[0122] Module object 750B of drawing 19 (B) becomes unnecessary [the embedding to the module object 100 of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [module object 750B], and becomes recyclable. Furthermore, since the actuator 106 is protected by the pedestal 360, it can protect an actuator 106 from contact outside. [0123] Drawing 20 (A) shows the sectional view of the ink container when equipping a container 1 with module object 700B. In this example, module object 700B is used as one of the attachment structures. The container 1 is equipped with module object 700B as the liquid-container attachment section 360 projects inside a container 1. A through tube 370 is formed in the attachment plate 350, and the oscillating section of a through tube 370 and an actuator 106 faces. Furthermore, a hole 382 is formed in the bottom wall of module object 700B, and the piezoelectric device applied part 363 is formed. As an actuator 106 closes one side of a hole 382, it is arranged. Therefore, ink contacts a diaphragm 176 through the hole 382 of the piezoelectric device applied part 363, and the through tube 370 of the attachment plate 350. Both the hole 382 of the piezoelectric device applied part 363 and the through tube 370 of the attachment plate 350 form an ink reservoir. The piezoelectric device applied part 363 and the actuator 106 are being fixed by the attachment plate 350 and the film member. The sealing structure 372 is formed in the connection of the liquid-container attachment section 360 and a container 1. The sealing structure 372 may be formed with reversible ingredients, such as synthetic resin, and may be formed with an O ring, although module object 700B of drawing 20 (A) and a container 1 are another objects -- drawing 20 (B) -- the piezoelectric device applied part of module object 700B may consist of some containers 1 like.

[0124] Module object 700B of drawing 20 (A) becomes unnecessary [the embedding to the module object of a reed wire shown in drawing 17 from drawing 13]. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [module object 700B], and becomes recyclable.

[0125] In case an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink adhered to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. However, since the liquid-container attachment section 360 has projected module object 700B inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.

[0126] Moreover, in the example of drawing 20 (A), a container 1 is equipped with some of diaphragms 176 and attachment plates 350 so that the ink in a container 1 may be contacted. In

the example of drawing 20 (A), the embedding to the module object of the electrode of reed wires 104a, 104b, 404a, 404b, 504a, and 504b shown in drawing 17 from drawing 13 becomes unnecessary. Therefore, a forming cycle is simplified. Furthermore, it becomes exchangeable [an actuator 106] and becomes recyclable.

[0127] Drawing 20 (B) shows the sectional view of an ink container as an example when equipping a container 1 with an actuator 106. In the ink cartridge by the example of drawing 20 (B), the protection member 361 is attached in the container 1 as another object in the actuator 106. Therefore, although the protection member 361 and the actuator 106 are not united as a module, they are one side, and the protection member 361 can protect them so that a user's hand cannot be touched at an actuator 106. The hole 380 prepared in the front face of an actuator 106 is arranged by the side attachment wall of a container 1. An actuator 106 contains the piezo-electric layer 160, the up electrode 164, the lower electrode 166, a diaphragm 176, and the attachment plate 350. A diaphragm 176 is formed in the top face of the attachment plate 350, and the lower electrode 166 is formed in the top face of a diaphragm 176. The piezo-electric layer 160 is formed in the top face of the lower electrode 166, and the up electrode 164 is formed in the top face of the piezo-electric layer 160. Therefore, the principal part of the piezo-electric layer 160 is formed so that it may be inserted by the principal part of the up electrode 164, and the principal part of the lower electrode 166 from the upper and lower sides. The circular part which is each principal part of the piezo-electric layer 160, the up electrode 164, and the lower electrode 166 forms a piezoelectric device. A piezoelectric device is formed on a diaphragm 176. A piezoelectric device and the oscillating field of a diaphragm 176 are the oscillating sections in which an actuator actually vibrates. The through tube 370 is formed in the attachment plate 350. Furthermore, the hole 380 is formed in the side attachment wall of a container 1. Therefore, ink contacts a diaphragm 176 through the hole 380 of a container 1, and the through tube 370 of the attachment plate 350. Both the hole 380 of a container 1 and the through tube 370 of the attachment plate 350 form an ink reservoir. Moreover, in the example of drawing 20 (B), since the actuator 106 is protected by the protection member 361, it can protect an actuator 106 from contact outside.

[0128] In addition, it may replace with drawing 20 (A) and the attachment plate 350 in the example of (B), and the substrate 178 of drawing 1 may be used.

[0129] Drawing 20 (C) shows an operation gestalt equipped with the mold structure 600 containing an actuator 106. In this example, the mold structure 600 is used as one of the attachment structures. The mold structure 600 has an actuator 106 and the mold section 364. An actuator 106 and the mold section 364 are fabricated by one. The mold section 364 is fabricated with reversible ingredients, such as silicon resin. The mold section 364 has a reed wire 362 inside. The mold section 364 is formed so that it may have two guide pegs prolonged from an actuator 106, the mold section 364 -- the mold section 364 and a container 1 -- liquid -- since it fixes densely, the edge of two guide pegs of the mold section 364 is formed in the shape of a semi-sphere. A container 1 is equipped with the mold section 364 so that an actuator 106 may project inside a container 1, and the oscillating section of an actuator 106 contacts the ink in a container 1. The up electrode 164, the piezo-electric layer 160, and the lower electrode 166 of an actuator 106 are protected from ink by the mold section 364.

[0130] For the mold structure 600 of drawing 20 (C), since the sealing structure 372 is unnecessary between the mold section 364 and a container 1, ink is a pile to the leakage from a container 1. Moreover, since it is the gestalt in which the mold structure 600 does not project from the exterior of a container 1, an actuator 106 can be protected from contact outside. In case

an ink cartridge shakes, an actuator 106 may incorrect-operate because the ink which ink was attached to the top face or side face of a container 1, and has hung down from the top face or side face of a container 1 contacts an actuator 106. Since the mold section 364 has projected the mold structure 600 inside the container 1, an actuator 106 does not incorrect-operate in the ink which has hung down from the top face and side face of a container 1.

[0131] Drawing 21 shows the operation gestalt of the ink cartridge and ink jet recording device using the actuator 106 shown in drawing 1. The ink jet recording device which has two or more ink induction 182 and electrode holders 184 corresponding to each ink cartridge 180 is equipped with two or more ink cartridges 180. Two or more ink cartridges 180 hold the ink of a class different, respectively, for example, a color. Each base of two or more ink cartridges 180 is equipped with the actuator 106 which is a means to detect an acoustic impedance at least. By equipping an ink cartridge 180 with an actuator 106, the ink residue in an ink cartridge 180 is detectable.

[0132] Drawing 22 shows the detail of the head section circumference of an ink jet recording device. An ink jet recording device has the ink induction 182, an electrode holder 184, the head plate 186, and a nozzle plate 188. Two or more formation of the nozzle 190 which injects ink is carried out at the nozzle plate 188. The ink induction 182 has the air supply opening 181 and the ink inlet 183. The air supply opening 181 supplies air to an ink cartridge 180. The ink inlet 183 introduces ink from an ink cartridge 180. An ink cartridge 180 has an air induction inlet 185 and the ink feed hopper 187. An air induction inlet 185 introduces air from the air supply opening 181 of the ink induction 182. The ink feed hopper 187 supplies ink to the ink inlet 183 of the ink induction 182. When an ink cartridge 180 introduces air from the ink induction 182, supply of the ink from the ink cartridge 180 to the ink induction 182 is urged. An electrode holder 184 opens for free passage the ink supplied through the ink induction 182 from the ink cartridge 180 on the head plate 186.

[0133] Drawing 23 shows other operation gestalten of an ink cartridge 180 shown in drawing 20. Base 194a by which ink cartridge 180A of drawing 23 (A) was aslant formed in the vertical direction is equipped with the actuator 106. Inside the ink container 194 of an ink cartridge 180, the breaking-the-water wall 192 is formed in the actuator 106 of predetermined height, and the faced location from the internal base of the ink container 194. Since it is aslant equipped with the actuator 106 to the vertical direction of the ink container 194, it becomes the ***** fitness of ink.

[0134] The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles are detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192, the wave of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented.

[0135] It is equipped with the actuator 106 of ink cartridge 180B of drawing 23 (B) on the side attachment wall of the feed hopper of the ink container 194. As long as it is near the ink feed hopper 187, the side attachment wall or base of the ink container 194 may be equipped with an actuator 106. Moreover, as for an actuator 106, it is desirable that the core of the cross direction of the ink container 194 is equipped. Since ink passes the ink feed hopper 187 and is supplied outside, ink and an actuator 106 contact certainly to an ink near end time by forming an actuator 106 near the ink feed hopper 187. Therefore, an actuator 106 can detect the time of an ink near

end certainly.

[0136] Furthermore, by forming an actuator 106 near the ink feed hopper 187, in case the cartridge holder on carriage is equipped with an ink container, positioning with the actuator 106 on an ink container and the contact on carriage becomes certain. In connection on an ink container and carriage, positive association with an ink feed hopper and a supply needle is the most important for the reason. It is because its tip of a supply needle is hurt, or a damage will be given to scaling structures, such as an O ring, and ink will begin to leak, if there is a gap. In order to prevent such a trouble, the ink jet printer usually has the special structure which can do exact alignment, when mounting an ink container on carriage. Therefore, by arranging an actuator near the feed hopper, the alignment of an actuator also becomes a positive thing at coincidence. Furthermore, alignment can be more certainly carried out by equipping the core of the cross direction of the ink container 194 with an actuator 106. When an ink container carries out axial rocking a core [a crosswise center line] at the time of wearing to a holder, it is because there are few the shakes.

[0137] Drawing 24 shows the operation gestalt of further others of an ink cartridge 180. The sectional view which expanded side-attachment-wall 194b of ink cartridge 180C which showed drawing 24 (A) in the sectional view of ink cartridge 180C, and showed drawing 24 (B) to drawing 24 (A), and drawing 24 (C) are the perspective drawing from the transverse plane. Ink cartridge 180C is formed on the circuit board 610 with same semi-conductor storage means 7 and actuator 106. As shown in drawing 24 (B) and (C), the semi-conductor storage means 7 is formed above the circuit board 610, and the actuator 106 is formed under the semi-conductor storage means 7 in the same circuit board 610. Side-attachment-wall 194b is equipped with variant O ring 614 so that the perimeter of an actuator 106 may be surrounded. Two or more formation of the caulking section 616 for joining the circuit board 610 to the ink container 194 is carried out at side-attachment-wall 194b. while the oscillating field of an actuator 106 can be made to perform contacting ink by joining the circuit board 610 to the ink container 194, and pushing variant O ring 614 against the circuit board 610 by the caulking section 616 -- the exterior and the interior of an ink cartridge -- liquid -- it is kept dense.

[0138] The terminal 612 is formed in the semi-conductor storage means 7 and semi-conductor storage means 7 neighborhood. A terminal 612 delivers the signal between the semi-conductor storage means 7 and the exteriors, such as ink jet storage. The semi-conductor storage means 7 may be constituted by the rewritable semiconductor memory of EEPROM etc. On the same circuit board 610, since it is, the semi-conductor storage means 7 and an actuator 106 end like 1 time of a shipfitter, formation, now in case an actuator 106 and the semi-conductor storage means 7 are attached in ink cartridge 180C. Moreover, the routing at the time of manufacture of ink cartridge 180C and recycle is simplified. Furthermore, since the mark of components are reduced, the manufacturing cost of ink cartridge 180C can be reduced.

[0139] An actuator 106 detects the consumption condition of the ink in the ink container 194. The semi-conductor storage means 7 stores the information on ink, such as an ink residue which the actuator 106 detected. That is, the semi-conductor storage means 7 stores the information about property parameters, such as the property of the ink used in case it detects, and an ink cartridge. The semi-conductor storage means 7 stores the resonance frequency of the time of an end, at i.e., the that the ink in the ink container 194 was consumed time, as one of the property parameters, when the ink in the ink container 194 is full beforehand (i.e., when ink is filled in the ink container 194). The ink in the ink container 194 may be stored when, as for the resonance frequency of full or an end condition, an ink jet recording device is equipped with an ink

container for the first time. Moreover, as for the resonance frequency of full or an end condition, the ink in the ink container 194 may be stored during manufacture of the ink container 194. Resonance frequency in case the ink in the ink container 194 is full or an end beforehand is stored in the semi-conductor storage means 7, and since dispersion at the time of detecting an ink residue by reading the data of resonance frequency by the ink jet recording apparatus side can be amended, it is correctly detectable that the ink residue decreased to the reference value.

[0140] Drawing 25 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180D shown in drawing 25 (A) equips side-attachment-wall 194b of the ink container 194 with two or more actuators 106. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. Two or more actuators 106 set spacing in the vertical direction, and are arranged at side-attachment-wall 194b. By setting two or more actuators 106 in the vertical direction, and arranging spacing for them in it at side-attachment-wall 194b, an ink residue is gradually detectable.

[0141] Ink cartridge 180E shown in drawing 25 (B) equips side-attachment-wall 194b of the ink container 194 with the actuator 606 long in the vertical direction. Change of the ink residue in the ink container 194 is continuously detectable in the vertical direction with the long actuator 606. the die length of an actuator 606 has the die length more than one half of height in side-attachment-wall 194b -- desirable -- drawing 25 (B) -- setting -- an actuator 606 -- side-attachment-wall 194b -- it has the die length to a lower limit mostly from upper limit.

[0142] Like ink cartridge 180D shown in drawing 25 (A), ink cartridge 180F shown in drawing 25 (C) equip side-attachment-wall 194b of the ink container 194 with two or more actuators 106, set predetermined spacing to confrontation of two or more actuators 106, and are equipped with the long breaking-the-water wall 192 in the vertical direction. It is desirable to use two or more really fabricated actuators 106 which were shown in drawing 5 as an actuator 106 of these plurality. The gap filled with ink is formed between an actuator 106 and the breaking-the-water wall 192. Moreover, spacing of the breaking-the-water wall 192 and an actuator 106 is vacated for extent with which ink is not held according to the capillary tube force. When the ink container 194 rolls, the wave of ink occurs in the ink container 194 interior by rolling, a gas and air bubbles will be detected by the impact with an actuator 106, and an actuator 106 may incorrect-operate by it. By establishing the breaking-the-water wall 192 like this invention, ***** of the ink of the actuator 106 neighborhood can be prevented and incorrect actuation of an actuator 106 can be prevented. Moreover, the air bubbles generated because ink rocks the breaking-the-water wall 192 prevent invading into an actuator 106.

[0143] Drawing 26 shows the operation gestalt of further others of an ink cartridge 180. Ink cartridge 180G of drawing 26 (A) have two or more septa 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of each septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180G have two or more hold rooms 213 divided as two or more septa 212 be alike, respectively. The pars basilaris ossis occipitalis of two or more hold rooms 213 is mutually open for free passage. In each of two or more hold rooms 213, top-face 194c of the ink container 194 is equipped with the actuator 106. It is desirable to use the really fabricated actuator 106 which was shown in drawing 5 as an actuator 106 of these plurality. an actuator 106 -- top-face 194c of the hold room 213 of the ink container 194 -- it is mostly arranged in the center. The capacity of the hold room 213 is becoming small gradually as the capacity of the hold room 213 has the largest ink feed hopper 187 side and it keeps away from the ink feed hopper 187 into the ink container 194. Therefore, spacing by which an actuator

106 is arranged is narrow as the ink feed hopper 187 side is large and keeps away from the ink feed hopper 187 into the ink container 194.

[0144] Since ink is discharged from the ink feed hopper 187 and air enters from an air induction inlet 185, ink is consumed at the hold room 213 of the direction in the inner part of ink cartridge 180G from the hold room 213 by the side of the ink feed hopper 187. For example, while the ink of the hold room 213 nearest to the ink feed hopper 187 was consumed and the water level of the ink of the hold room 213 nearest to the ink feed hopper 187 has fallen, ink is filled at other hold rooms 213. If all the ink of the hold room 213 nearest to the ink feed hopper 187 is consumed, air will count from the ink feed hopper 187, and will trespass upon the 2nd hold room 213, the ink in the 2nd hold room 213 will begin to be consumed, and the water level of the ink of the 2nd hold room 213 will begin to fall. It counts from the ink supply room 187, and ink is filled at this time at the hold room 213 of the 3rd henceforth. Thus, ink is consumed in order at the hold room 213 distant from the hold room 213 near the ink feed hopper 187.

[0145] Thus, since an actuator 106 sets spacing to top-face 194c of the ink container 194 and is arranged every hold room 213 at it, as for an actuator 106, reduction of the amount of ink is gradually detectable. Furthermore, since the capacity of the hold room 213 is becoming small gradually into the ink feed hopper 187 to the hold room 213, it can detect frequency highly, so that the time interval to which an actuator 106 detects reduction of the amount of ink becomes small gradually and approaches an ink end.

[0146] Ink cartridge 180H of drawing 26 (B) have one septum 212 caudad prolonged from top-face 194c of the ink container 194. Since predetermined spacing is vacated, the lower limit of a septum 212 and the base of the ink container 194 are opening the pars basilaris ossis occipitalis of the ink container 194 for free passage. Ink cartridge 180H have two hold rooms 213a and 213b divided by the septum 212. The pars basilaris ossis occipitalis of the hold rooms 213a and 213b is mutually open for free passage. The capacity of hold room 213a by the side of the ink feed hopper 187 is seen from the ink feed hopper 187, and is larger than the capacity of hold room 213b in the direction of back. As for the capacity of hold room 213b, it is desirable that it is smaller than the one half of the capacity of hold room 213a.

[0147] Top-face 194c of hold room 213b is equipped with an actuator 106. Furthermore, the buffer 214 which is the slot which catches the air bubbles into which it goes at the time of manufacture of ink cartridge 180H is formed in hold room 213b. In drawing 26 (B), a buffer 214 is formed as a slot which extends in the upper part from side-attachment-wall 194b of the ink container 194. Since the air bubbles which invaded in ink hold room 213b are caught, as for a buffer 214, an actuator 106 can prevent an ink end and the incorrect actuation to detect with air bubbles. Moreover, ink can be consumed to the last by applying the amendment corresponding to the consumption condition of the ink in hold room 213a grasped with the dot counter to the amount of ink after an ink near end is detected until it will be in ink and a condition completely by forming an actuator 106 in top-face 194c of hold room 213b. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0148] As for drawing 26 (C), hold room 213b of ink cartridge 180I of drawing 26 (B) is filled up with the porosity member 216. The porosity member 216 is installed so that the whole space from the top face in hold room 213b to an inferior surface of tongue may be filled. The porosity member 216 contacts an actuator 106. During the reciprocating motion the time of an ink container falling, and on carriage, air may invade in ink hold room 213b, and this may cause incorrect actuation of an actuator 106. However, if it has the porosity member 216, it can prevent

catching air and air going into an actuator 106. Moreover, since the porosity member 216 holds ink, when an ink container shakes, it can prevent applying ink to an actuator 106 and an actuator 106 incorrect-detecting those without ink with those with ink. As for the porosity member 216, it is desirable to install in the hold room 213 where capacity is the smallest. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0149] Drawing 26 (D) shows ink cartridge 180J from which the porosity member 216 of ink cartridge 180I of drawing 26 (C) is constituted by two kinds of porosity members 216A and 216B from which an aperture differs. Porosity member 216A is arranged above porosity member 216B. The aperture of upper porosity member 216A is larger than the aperture of lower porosity member 216B. Or porosity member 216A is formed by the member with low liquid compatibility rather than porosity member 216B. Since the capillary tube force is larger than large porosity member 216A of an aperture, the ink in hold room 213b gathers for lower porous chamber portion material 216B, and the direction of small porosity member 216B of an aperture is held. Therefore, once even an actuator 106 reaches and air detects those without ink, ink will reach an actuator again and it will not detect with those with ink. Furthermore, ***** of about 106-actuator ink becomes good by ink being absorbed by porosity member 216B of a side far from an actuator 106, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Moreover, by forming an actuator 106 in top-face 194c of nature of hold 213b, amendment can be applied to the amount of ink after an ink near end is detected until it will be in ink and a condition completely, and ink can be consumed to the last. Furthermore, the amount of ink after ink near end detection which can be consumed is changeable by adjusting the capacity of hold room 213b by changing the die length and spacing of a septum 212 etc.

[0150] Drawing 27 is the sectional view showing ink cartridge 180K which is other operation gestalten of ink cartridge 180I shown in drawing 26 (C). The porosity member 216 of an ink cartridge 180 shown in drawing 27 is compressed so that the horizontal cross section of the lower part of the porosity member 216 becomes small gradually towards the direction of the base of the ink container 194, and it is designed so that an aperture may become small. In order to compress ink cartridge 180K of drawing 27 (A) so that the aperture in the direction of under the porosity member 216 becomes small, the rib is prepared in the side attachment wall. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the porosity member 216 lower part, and is held. By ink being absorbed by the porosity member 216 lower part of a side far from an actuator 106, ***** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which ink cartridge 180K top face was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.

[0151] On the other hand, in order that the horizontal cross section of the lower part of the porosity member 216 may compress ink cartridge 180L of drawing 27 (B) and drawing 27 (C) in the cross direction of the ink container 194 to become small gradually towards the base of the ink container 194, the horizontal cross section of a hold room is becoming small gradually towards the direction of the base of the ink container 194. Since the aperture of the porosity member 216 lower part is small by being compressed, ink is collected in the lower part of the porosity

member 216, and is held. By ink being absorbed by the lower part of porosity member 216B of a side far from an actuator 106, ***** of about 106-actuator ink becomes good, and the variation of the acoustic-impedance change when detecting ink existence becomes large. Therefore, when ink shakes, ink is applied to the actuator 106 with which the top face of ink cartridge 180L was equipped, it can keep, and an actuator 106 can prevent incorrect-detecting those without ink with those with ink.

[0152] Drawing 28 shows the operation gestalt of further others of the ink cartridge which used the actuator 106. Ink cartridge 220A of drawing 28 (A) has the 1st septum 222 formed so that it might extend from the top face of ink cartridge 220A to a lower part. Since predetermined spacing is vacated between the lower limit of the 1st septum 222, and the base of ink cartridge 220A, ink can flow into the ink feed hopper 230 through the base of ink cartridge 220A. From the 1st septum 222, the 2nd septum 224 is formed in the ink feed hopper 230 side so that it may extend more nearly up than the base of ink cartridge 220A. Since predetermined spacing is vacated between the upper limit of the 2nd septum 224, and an ink cartridge 220A top face, ink can flow into the ink feed hopper 230 through the top face of ink cartridge 220A.

[0153] By the 1st septum 222, it sees from the ink feed hopper 230, and 1st hold room 225a is formed in the direction in the inner part of the 1st septum 222. On the other hand, by the 2nd septum 224, it sees from the ink feed hopper 230, and 2nd hold room 225b is formed in the near side of the 2nd septum 224. The capacity of 1st hold room 225a is larger than the capacity of 2nd hold room 225b. The capillary tube way 227 is formed by vacating only spacing which can cause capillarity between the 1st septum 222 and the 2nd septum 224. Therefore, the ink of 1st hold room 225a is brought together in the capillary tube way 227 according to the capillary tube force of the capillary tube way 227. Therefore, a gas and air bubbles can prevent mixing to 2nd hold room 225b. Moreover, the water level of the ink in 2nd hold room 225b can descend gradually stably. Since it sees from the ink feed hopper 230 and 1st hold room 225a is formed in the back from 2nd hold room 225b, after the ink of 1st hold room 225a is consumed, the ink of 2nd hold room 225b is consumed.

[0154] The side attachment wall by the side of the ink feed hopper 230 of ink cartridge 220A, i.e., the side attachment wall by the side of the ink feed hopper 230 of 2nd hold room 225b, is equipped with the actuator 106. An actuator 106 detects the consumption condition of the ink in 2nd hold room 225b. By equipping the side attachment wall of 2nd hold room 225b with an actuator 106, when near, an ink residue is stably detectable with an ink end. Furthermore, it can set up freely which time the ink residue in is made into an ink end by changing the height which equips the side attachment wall of 2nd hold room 225b with an actuator 106. Since an actuator 106 is not influenced by the ink by rolling of ink cartridge 220A of rolling when ink is supplied to 2nd hold room 225b by the capillary tube way 227 from 1st hold room 225a, an actuator 106 can measure an ink residue certainly. Furthermore, since the capillary tube way 227 holds ink, ink protects flowing backwards to 1st hold room 225a from 2nd hold room 225b.

[0155] The check valve 228 is formed in the top face of ink cartridge 220A. By the check valve 228, when ink cartridge 220A rolls, it can prevent ink leaking to the ink cartridge 220A exterior. Furthermore, the evaporation from ink cartridge 220A of ink can be prevented by installing a check valve 228 in the top face of ink cartridge 220A. If the ink in ink cartridge 220A is consumed and the negative pressure in ink cartridge 220A exceeds the pressure of a check valve 228, a check valve 228 will open, air will be inhaled to ink cartridge 220A, it will close after that, and the pressure in ink cartridge 220A will be held uniformly.

[0156] Drawing 28 (C) and (D) show the cross section of the detail of a check valve 228. The

check valve 228 of drawing 28 (C) has the valve 232 which has wing 232a formed of rubber. The air hole 233 with the exterior of an ink cartridge 220 counters wing 232a, and is prepared in an ink cartridge 220. An air hole 233 is opened and closed by wing 232a. If the ink in an ink cartridge 220 decreases in number and, as for a check valve 228, the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, wing 232a will open inside an ink cartridge 220, and will adopt external air in an ink cartridge 220. The check valve 228 of drawing 28 (D) has the valve 232 and spring 235 which were formed of rubber. If the negative pressure in an ink cartridge 220 exceeds the pressure of a check valve 228, a valve 232 will press and open a spring 235, will inhale external air in an ink cartridge 220, will close a check valve 228 after that, and it will hold the negative pressure in an ink cartridge 220 uniformly.

[0157] Ink cartridge 220B of drawing 28 (B) arranges the porosity member 242 to 1st hold room 225a instead of forming a check valve 228 in ink cartridge 220A of drawing 28 (A). The porosity member 242 prevents ink leaking to the exterior of ink cartridge 220B, when ink cartridge 220B rolls, while holding the ink in ink cartridge 220B.

[0158] As mentioned above, in the carriage and the ink cartridge of another object with which carriage is equipped, although the case where an ink cartridge or carriage was equipped with an actuator 106 was described, it unites with carriage and the ink tank with which an ink jet recording apparatus is equipped with carriage may be equipped with an actuator 106. Furthermore, the ink tank of the off-carriage method which supplies ink to carriage may be equipped with an actuator 106 through the tube of carriage and another object etc. Furthermore, the ink cartridge which the recording head and the ink container were united and was constituted exchangeable may be equipped with the actuator of this invention.

[0159] As mentioned above, although this invention was explained using the gestalt of operation, the technical range of this invention is not limited to the range given in the gestalt of the above-mentioned implementation. Various modification or amelioration can be added to the gestalt of the above-mentioned implementation. It is clear from the publication of a claim that the gestalt's which added such modification or amelioration it may be contained in the technical range of this invention.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is drawing showing the detail of an actuator 106.

[Drawing 2] It is drawing showing the circumference of an actuator 106, and its equal circuit.

[Drawing 3] It is drawing showing the relation between the consistency of ink, and the resonance frequency of the ink detected by the actuator 106.

[Drawing 4] It is drawing showing the back EMF wave of an actuator 106.

[Drawing 5] It is drawing showing other operation gestalten of an actuator 106.

[Drawing 6] It is drawing showing some cross sections of the actuator 106 shown in drawing 5.

[Drawing 7] It is drawing showing the cross section of the whole actuator 106 shown in drawing 6.

[Drawing 8] It is drawing showing the manufacture approach of the actuator 106 shown in drawing 5.

[Drawing 9] It is drawing showing the operation gestalt of further others of the ink cartridge of

this invention.

[Drawing 10] It is drawing showing other operation gestalten of through tube 1c.

[Drawing 11] It is drawing showing other operation gestalten of an actuator 660.

[Drawing 12] It is drawing showing the operation gestalt of further others of an actuator 670.

[Drawing 13] It is the perspective view showing the module object 100.

[Drawing 14] It is the exploded view showing the configuration of the module object 100 shown in drawing 13 .

[Drawing 15] It is drawing showing other operation gestalten of the module object 100.

[Drawing 16] It is the exploded view showing the configuration of the module object 100 shown in drawing 15 .

[Drawing 17] It is drawing showing the operation gestalt of further others of the module object 100.

[Drawing 18] It is drawing showing the example of the cross section which equipped the ink container 1 with the module object 100 shown in drawing 13 .

[Drawing 19] It is drawing showing the operation gestalt of further others of the module object 100.

[Drawing 20] It is drawing showing the operation gestalt of further others of the module object 100.

[Drawing 21] It is drawing showing the operation gestalt of the ink cartridge and ink jet recording device using the actuator 106 shown in drawing 1 and drawing 2 .

[Drawing 22] It is drawing showing the detail of an ink jet recording device.

[Drawing 23] It is drawing showing other operation gestalten of an ink cartridge 180 shown in drawing 22 .

[Drawing 24] It is drawing showing the operation gestalt of further others of an ink cartridge 180.

[Drawing 25] It is drawing showing the operation gestalt of further others of an ink cartridge 180.

[Drawing 26] It is drawing showing the operation gestalt of further others of an ink cartridge 180.

[Drawing 27] It is drawing showing other operation gestalten of an ink cartridge 180 shown in drawing 26 (C).

[Drawing 28] It is drawing showing the operation gestalt of further others of the ink cartridge using the module object 100.

[Description of Notations]

1 ... Container

1a ... Base

1b ... Side attachment wall

1c, 940a ... Through tube

1d ... Side face

1e, 1f ... Level difference section

1g, 1h ... Slot

2 ... Ink feed hopper

67 ... Plate

68 ... Float

71 ... Adhesives layer

78, 80, 178 ... Substrate

73, 82, a piezo-electric diaphragm
74 75 ... Ink absorber
76 ... Packing
77 ... Caulking hole
81 ... Crevice
100,400 500,700 ... Module object
101, 401, 501 ... Liquid-container attachment section
102 ... Pedestal
104 362 ... Reed wire
105, 405, 505 ... Piezoelectric device applied part
106, 650, 660, 670 ... Actuator
108 ... Film
110 ... Plate
112, 412, 370 ... Through tube
113 ... Crevice
114 ... Opening
116 ... Cylinder section
160 ... Piezo-electric layer
162 ... Cavity
164 ... Up electrode
166 ... Lower electrode
168 ... Up electrode terminal
170 ... Lower electrode terminal
172 ... Auxiliary electrode
174 ... Piezoelectric device
176 ... Diaphragm
180 ... Ink cartridge
181 ... Air supply opening
182 ... Ink induction
183 ... Ink inlet
184 ... Electrode holder
185 ... Air induction inlet
186 ... Head plate
187 ... Ink feed hopper
188 ... Nozzle plate
190 ... Nozzle
192 ... Breaking-the-water wall
194 ... Ink container
194a ... Base
194b ... Side attachment wall
194c ... Top face
212 ... Septum
213, 213a, 213b ... Hold room
214 ... Buffer
216, 216a, 216b ... Porosity member
220 ... Ink cartridge

222 ... The 1st septum
224 ... The 2nd septum
225a ... 1st hold room
225b ... 2nd hold room
227 ... Capillary tube way
228 ... Check valve
230 ... Ink feed hopper
232 ... Valve
232a ... Wing
233 ... Air hole
235 ... Spring
242 ... Porosity member
250 ... Carriage
252 ... Recording head
254 ... Ink supply needle
256 ... Subtank unit
258 258' ... Heights
260 260' ... Elastic wave generating means
262 ... Ink room
266 ... Film valve
270 ... Valve element
272 ... Ink cartridge
274 ... Container
274a ... Base
274b ... Side face
276 ... Ink feed hopper
278 ... Crevice
280 280' ... Gelation material
282 ... Packing
284 ... Spring
286 ... Valve element
288 ... Semi-conductor storage means
290 ... Container
290a ... Base
292, 294, 296 ... Ink room
298, 300, 302 ... Ink feed hopper
304, 306, 308 ... Gelation material
310, 312, 314 ... Crevice
316 ... Plate
318 ... Float
350 ... Attachment plate
360 ... Liquid-container attachment section
364 ... Mold section
372 ... Sealing structure
402 502 ... Pedestal
403 503 ... Cylinder section

404 504 ... Reed wire
408 508 ... Film
410 510 ... Plate
413 513 ... Crevice
414 514 ... Opening
600 ... Mold structure
606 ... Actuator
610 ... Circuit board
612 ... Terminal
940 941 ... Green sheet
942 944 ... Conductive layer
944' ... Connection
947 948 ... Spacing member
delta h1, delta h2 ... Change of an oil level
K ... Ink

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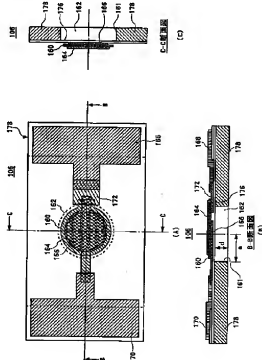
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(54)【発明の名称】 圧電装置、モジュール体、液体容器、及びインクカートリッジ

(57)【要約】

【課題】 検出電極取付けに起因する複雑なシール構造を要することなく、インク残量を正確に検出すること。

【解決手段】 液体容器に装着され、液体容器内の液体の消費状態を検知する圧電装置であって、圧電素子の変形によって振動が発生する振動部を有し、振動部はその中心に対して対称な形状を有する圧電装置。



【特許請求の範囲】

【請求項1】 液体容器に装着され、該液体容器内の液体の消費状態を検知する圧電装置であって、前記圧電装置は、圧電素子の変形によって振動が発生する振動部を有し、該振動部がその中心に対して対称な形状を有することを特徴とする圧電装置。

【請求項2】 前記圧電装置の前記振動部が、ほぼ円形の形状を有することを特徴とする請求項1に記載の圧電装置。

【請求項3】 前記圧電装置が、圧電層、該圧電層の上面に設けられた上部電極、前記圧電層の下面に設けられた下部電極、及び上面が前記下部電極と接し、下面の一部が前記液体容器内の前記液体と接触する振動板を備え、前記振動部は、前記圧電層、前記上部電極、前記下部電極、及び前記振動板のそれぞれの少なくとも一部を含むことを特徴とする請求項1又は2に記載の圧電装置。

【請求項4】 前記圧電層、前記上部電極、及び前記下部電極のそれぞれの主部が、前記振動部とほぼ同心円の円形の形状であることを特徴とする請求項3に記載の圧電装置。

【請求項5】 前記圧電装置は、上面が前記振動板の前記液体と接触する前記下面側と接し、下面が前記液体容器内の前記液体と接触する基板を更に備え、前記基板が、前記振動部に面する位置に前記液体と接触する空洞を有することを特徴とする請求項3に記載の圧電装置。

【請求項6】 前記空洞が、前記振動部とほぼ同心円の円形状であることを特徴とする請求項5に記載の圧電装置。

【請求項7】 前記残留振動による前記振動板の変形が、前記基板の変形よりも大きいことを特徴とする請求項5に記載の圧電装置。

【請求項8】 前記振動部の振動の節が、前記空洞の外周部付近に位置することを特徴とする請求項5に記載の圧電装置。

【請求項9】 前記圧電装置は、上面が前記振動板の前記液体と接触する前記下面側と接し、下面が前記液体容器の内側を向く取付部材を更に備え、前記取付部材が、前記振動部の中心部に開口を有することを特徴とする請求項3に記載の圧電装置。

【請求項10】 前記圧電装置が、前記振動部近傍の音響インピーダンスの変化を検知することにより前記液体容器内の液体の消費状態を検知することを特徴とする請求項1に記載の圧電装置。

【請求項11】 前記圧電装置が、前記振動部に残留す

る残留振動によって発生する逆起電力に基づいて前記音響インピーダンスの変化を検知し、前記液体容器内の液体の消費状態を検知することを特徴とする請求項10に記載の圧電装置。

【請求項12】 該振動部が、振動の共振モードにおいて低次の共振モードに単一のピークが出現する振動が発生することを特徴とする請求項1に記載の圧電装置。

【請求項13】 請求項1乃至12記載の圧電装置が装着されたことを特徴とする液体容器。

【請求項14】 請求項1乃至12記載の圧電装置と、前記圧電装置を前記液体容器に取付けるための、前記圧電装置と一体化された取付構造体とを備えたことを特徴とするモジュール体。

【請求項15】 前記取付構造体が、前記液体容器の内部へ張り出す張り出し部を含み、前記張り出し部の中心線上前記振動部の中心が配置されたことを特徴とする請求項14に記載のモジュール体。

【請求項16】 前記張り出し部が、円筒形であることを特徴とする請求項15に記載のモジュール体。

【請求項17】 前記圧電装置を前記上部電極及び前記下部電極と電気的に接続する端子を更に備えたことを特徴とする請求項16に記載のモジュール体。

【請求項18】 請求項14乃至17に記載のモジュール体が装着されたことを特徴とする液体容器。

【請求項19】 請求項13または18に記載の液体容器にインクジェット記録装置に供給するインクを収容したことを特徴とするインクカートリッジ。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、音響インピーダンスの変化を検出することで、その中でも特に共振周波数の変化を検出することでインク等の液体を収容する液体容器内の液体の消費状態を検知するための圧電装置（アクチュエータ）が備えられた液体容器に関する。さらに詳しくは、圧力発生手段により圧力発生室のインクを印刷データに対応させて加圧し、ノズル開口からインク滴を吐出させて印刷するインクジェット記録装置に連した圧電装置、モジュール体、液体容器、及びインクカートリッジに関するものである。

【0002】

【従来の技術】インクジェット記録装置は、圧力発生室を加圧する圧力発生手段と、加圧されたインクをノズル開口からインク滴として吐出するノズル開口とを備えたインクジェット記録ヘッドをキャリッジに搭載する。インクジェット記録装置は、インクタンクのインクを流路を介して記録ヘッドに供給しながら印刷を継続可能に構成されている。インクタンクは、インクが消費された時点で、ユーザが簡単に交換できるように着脱可能なカートリッジとして構成されている。

【0003】従来、インクカートリッジのインク消費の

管理方法として、記録ヘッドでのインク滴の吐出数やメンテナンスにより吸引されたインク量をソフトウェアにより積算してインク消費を計算により管理する方法と、インクカートリッジに液面検出用の電極を取付けることにより、実際にインクが所定量消費された時点进行管理する方法などがある。

【0004】しかしながら、ソフトウェアによりインク滴の吐出数やインク量を積算してインク消費を計算上管理する方法は、ユーザサイドでの印刷形態等により誤差が生じたり、また同一カートリッジの再装着時には大きな誤差が生じるという問題がある。また、使用環境により、例えば室温が極端な高低、あるいはインクカートリッジの開封後の経過時間などによってインクカートリッジ内の圧力やインクの粘度が変化して、計算上のインク消費量と実際の消費量との間に無視できない誤差が生じてしまうという問題もあった。一方、電極によりインクが消費された時点进行管理する方法は、インクの実量を検出できるため、インク残量を高い信頼性で管理できる。しかしながら、インクの液面の検出をインクの導電性に頼るので、検出可能なインクの種類が限定されたり、また電極のシール構造が複雑化する問題がある。また、電極の材料として通常は導電性が良く耐腐食性も高い貴金属を使用するので、インクカートリッジの製造コストがかなり高いという問題もあった。さらに、2本の電極を装着する必要があるため、製造工程が長くなり結果として製造コストがかかってしまうという問題もあった。

【0005】

【発明が解決しようとする課題】そこで本発明は、上記の課題を解決することのできる、インク残量を正確に検出でき、かつ複雑なシール構造を不要とした、液体容器に装着される圧電装置及びモジュールを提供することを目的とする。この目的は特許請求の範囲における独立項に記載の特徴の組み合わせにより達成される。また従属項は本発明の更なる有利な具体例を規定する。

【0006】

【課題を解決するための手段】即ち、本発明の第1の形態における圧電装置は、液体容器に装着され、液体容器内の液体の消費状態を検知する圧電装置であって、前記圧電装置は、圧電素子の変形によって振動が発生する振動部を有し、振動部は、その中心に対して対称な形状を有することが好ましい。

【0007】また、圧電装置の振動部は、ほぼ円形の形状を有することが好ましい。更に、圧電装置が、圧電層、圧電層の上面に設けられた上部電極、圧電層の下面に設けられた下部電極、及び上面が下部電極と接し、下面の一部が液体容器内の液体と接触する振動板を備え、振動部は、圧電層、上部電極、下部電極、及び振動板のそれぞれの少なくとも一部を含むことが好ましい。更に、圧電層、上部電極、及び下部電極のそれぞれの主部が、振動部とほぼ同心円の円形の形状であることが好ま

しい。

【0008】また、圧電装置は、上面が振動部の液体と接触する下面側と接し、下面が液体容器内の液体と接触する基板を更に備え、基板が、振動部に面する位置に液体と接触する空洞を有することが好ましい。空洞は、振動部とほぼ同心円の円形状であることが好ましい。また、残留振動による振動板の変形が、基板の変形よりも大きいことが好ましい。振動部の振動の節が、空洞の外周部付近に位置してもよい。圧電装置は、上面が振動板の液体と接触する下面側と接し、下面が液体容器の内側を向く取付部材を更に備え、取付部材が、振動部の中心部に開口を有することが好ましい。更に、上記の圧電装置が装着された液体容器であることが好ましい。

【0009】本発明の第2の形態におけるモジュール体は、上記の圧電装置と、圧電装置を液体容器に取付けるための、圧電装置と一体化された取付構造体とを備えることが好ましい。

【0010】取付構造体が、液体容器の内部へ張り出す張り出し部を含み、張り出し部の中心線上に振動部の中心が配置されてもよい。更に、張り出し部が、円筒形であってもよい。圧電装置の上部電極及び下部電極に駆動信号を与える端子を更に備えてもよい。また、上記のモジュール体が装着された液体容器であることが好ましい。また、上記の液体容器にインクジェット記録装置に供給するインクを収容するインクカートリッジであってもよい。

【0011】なお上記の発明の概要は、本発明の必要な特徴の全てを列挙したものではなく、これらの特徴群のサブコンビネーションも又発明となりうる。

【0012】

【発明の実施の形態】以下、発明の実施の形態を通じて本発明を詳細に説明する。以下の実施形態はクレームにかかる発明を限定するものではなく、又実施形態の中で説明されている特徴の組み合わせの全てが発明の解決手段に必須であるとは限らない。

【0013】本発明の基本的概念は、振動現象を利用することで、液体容器内の液体の状態（液体容器内の液体の有無、液体の量、液体の水位、液体の種類、液体の組成を含む）を検出することである。具体的な振動現象を利用した液体容器内の液体の状態の検出としてはいくつかの方法が考えられる。例えば弾性波発生手段が液体容器の内部に対して弾性波を発生し、液面あるいは対向する壁によって反射する反射波を受波することで、液体容器内の媒体およびその状態の変化を検出する方法がある。また、これとは別に、振動する物体の振動特性から音響インピーダンスの変化を検知する方法もある。音響インピーダンスの変化を利用する方法としては、圧電素子を有する圧電装置またはアクチュエータの振動を振動させ、その後振動部に残留する残留振動によって生ずる逆起電力を測定することによって、共振周波数また

は逆起電力波形の振幅を検出することで音響インピーダンスの変化を検知する方法や、測定機、例えば伝送回路等のインピーダンスアナライザによって液体のインピーダンス特性またはアドミッタンス特性を測定し、電流値や電圧値の変化または、振動を液体に与えたときの電流値や電圧値の周波数による変化を測定する方法がある。以下、圧電装置またはアクチュエータの動作原理の詳細について説明する。

【0014】図1および図2は、圧電装置の一実施形態であるアクチュエータ106の詳細および等価回路を示す。ここでいうアクチュエータは、少なくとも音響インピーダンスの変化を検知して液体容器内の液体の消費状態を検出する方法に用いられる。特に、残留振動により共振周波数の検出することで、少なくとも音響インピーダンスの変化を検知して液体容器内の液体の消費状態を検出する方法に用いられる。図1(A)は、アクチュエータ106の拡大平面図である。図1(B)は、アクチュエータ106のB-B断面を示す。図1(C)は、アクチュエータ106のC-C断面を示す。さらに図2

(A)および図2(B)は、アクチュエータ106の等価回路を示す。また、図2(C)および図2(D)は、それぞれインクカートリッジ内にインクが満たされているときのアクチュエータ106を含む周辺およびその等価回路を示し、図2(E)および図2(F)は、それぞれインクカートリッジ内にインクが無いときのアクチュエータ106を含む周辺およびその等価回路を示す。

【0015】アクチュエータ106は、ほぼ中央に円形状の開口161を有する基板178と、開口161を被覆するように基板178の一方の面(以下、表面という)に配備される振動板176と、振動板176の表面の側に配置される圧電層160と、圧電層160を両方からはさみこむ上部電極164および下部電極166と、上部電極164と電氣的に結合する上部電極端子168と、下部電極166と電氣的に結合する下部電極端子170と、上部電極164および上部電極端子168の間に設けられ、かつ両者を電氣的に結合する補助電極172と、を有する。圧電層160、上部電極164および下部電極166はそれぞれの主要部として円形部分を有する。圧電層160、上部電極164および下部電極166のそれぞれの円形部分は圧電素子を形成する。

【0016】振動板176は、基板178の表面に、開口161を覆うように形成される。キャピティ162は、振動板176の開口161と面する部分と基板178の表面の開口161とによって形成される。基板178の圧電素子とは反対側の面(以下、裏面という)は液体容器側に面しており、キャピティ162は液体と接触するように構成されている。キャピティ162内に液体が入っても基板178の表面側に液体が漏れないように、振動板176は基板178に対して液密に取り付けられる。

【0017】下部電極166は振動板176の表面、即ち液体容器とは反対側の面に位置しており、下部電極166の主要部である円形部分の中心と開口161の中心とがほぼ一致するように取り付けられている。なお、下部電極166の円形部分の面積が開口161の面積よりも小さくなるように設定されている。一方、上部電極166の表面側には、圧電層160が、その円形部分の中心と開口161の中心とがほぼ一致するように形成されている。圧電層160の円形部分の面積は、開口161の面積よりも小さく、かつ下部電極166の円形部分の面積よりも大きくなるように設定されている。

【0018】一方、圧電層160の表面側には、上部電極164が、その主要部である円形部分の中心と開口161の中心とがほぼ一致するように形成される。上部電極164の円形部分の面積は、開口161および圧電層160の円形部分の面積よりも小さく、かつ下部電極166の円形部分の面積よりも大きくなるよう設定されている。

【0019】したがって、圧電層160の主要部は、上部電極164の主要部と下部電極166の主要部とによって、それぞれ表面側と裏面側とから挟みこまれる構造となっていて、圧電層160を効果的に変形駆動することができ。圧電層160、上部電極164および下部電極166のそれぞれの主要部である円形部分がアクチュエータ106における圧電素子を形成する。上述のように圧電素子は振動板176に接している。また、上部電極164の円形部分、圧電層160の円形部分、下部電極166の円形部分および開口161のうちで、面積が最も大きいのは開口161である。この構造によって、振動板176のうち実際に振動する振動領域は、開口161によって決定される。また、上部電極164の円形部分、圧電層160の円形部分および下部電極166の円形部分の面積が小さいので、振動板176がより振動しやすくなる。さらに、圧電層160と電氣的に接続する下部電極166の円形部分および上部電極164の円形部分のうち、下部電極166の円形部分の方が小さい。従って、下部電極166の円形部分が圧電層160のうち圧電効果を生ずる部分を決定する。

【0020】したがって、圧電層160の主要部は、上部電極164の主要部と下部電極166の主要部とによって、それぞれ表面側と裏面側とから挟みこまれる構造となっていて、圧電層160を効果的に変形駆動することができ。圧電層160、上部電極164および下部電極166のそれぞれの主要部である円形部分がアクチュエータ106における圧電素子を形成する。上述のように圧電素子は振動板176に接している。また、上部電極164の円形部分、圧電層160の円形部分、下部電極166の円形部分および開口161のうちで、面積が最も大きいのは開口161である。この構造によ

て、振動板 176 のうち実際に振動する振動領域は、開口 161 によって決定される。また、上部電極 164 の円形部分、圧電層 160 の円形部分および下部電極 166 の円形部分は開口 161 より面積が小さいので、振動板 176 がより振動しやすくなる。さらに、圧電層 160 と電氣的に接続する下部電極 166 の円形部分および上部電極 164 の円形部分のうち、下部電極 166 の円形部分の方が小さい。従って、下部端子 166 の円形部分が圧電層 160 のうち圧電効果を生ずる部分を決定する。

【0021】圧電素子を形成する圧電層 160、上部電極 164、及び下部電極 166 の円形部分は、その中心が、開口部 161 の中心とほぼ一致する。また、振動板 176 の振動部分を決定する円形状の開口部 161 の中心は、アクチュエータ 106 のほぼ中心に設けられている。したがって、アクチュエータ 106 の振動部の中心は、アクチュエータの中心とほぼ一致する。更に、圧電素子の主部及び、振動板 176 の振動部分が、円形な形状を有するので、アクチュエータ 106 の振動部は、アクチュエータ 106 の中心に対して対称な形状である。

【0022】振動部が、アクチュエータ 106 の中心に対して対称な形状であるので、構造の非対称性から生じる不要な振動を励起しないようにすることができる。そのため、共振周波数の検出精度が向上する。更に、振動部が、アクチュエータ中心に対して対称な形状であるので、製造しやすく、圧電素子ごとの形状のばらつきを小さくできる。したがって、圧電素子ごとの共振周波数のばらつきが小さくなる。また、振動部が、等方的な形状であるので、接着の際、固定のばらつきの影響を受けにくい。液体容器に均等に接着される。したがって、アクチュエータ 106 の液体容器への実装性がよい。

【0023】更に、振動板 176 の振動部分が、円形な形状を有するので、圧電層 160 の残留振動の共振モードにおいて、低次、例えば一次の共振モードが支配的となり、単一のピークが出現する。そのため、ピークとノイズとを、明確に区別することができるので、共振周波数を明確に検出することができる。また、円形な形状の振動板 176 の振動部分の面積を大きくすることによって、逆起電力波形の振幅及び液体の有無による共振周波数の振幅の差が大きくなり、共振周波数の検出の精度を更に向上できる。

【0024】振動板 176 の振動による変位は、基板 178 の振動による変位よりもはるかに大きい。アクチュエータ 106 は、コンプライアンスの小さい、すなわち振動によって変位しにくい基板 178 と、コンプライアンスの大きい、すなわち振動によって変位しやすい振動板 176 との 2 層構造を有する。この 2 層構造によって、基板 178 によって液体容器部に確実に固定されながら、かつ振動による振動板 176 の変位を大きくできるの、逆起電力波形の振幅及び液体の有無による共振周

波数の振幅の差が大きくなり、共振周波数の検出の精度が向上できる。更に、振動板 176 のコンプライアンスが大きいため、振動の減衰が小さくなり、共振周波数の検出の精度が向上できる。また、アクチュエータ 106 の振動部は、キャパシタ 162 の外周部、すなわち開口部 161 の縁付近に位置する。

【0025】上部電極端子 168 は、補助電極 172 を介して上部電極 164 と電氣的に接続するように振動板 176 の表面側に形成される。一方、下部電極端子 170 は、下部電極 166 に電氣的に接続するように振動板 176 の表面側に形成される。上部電極 164 は、圧電層 160 の表面側に形成されるため、上部電極端子 168 と接続する途中において、圧電層 160 の厚さと下部電極 166 の厚さとの和に等しい段差を有する必要がある。上部電極 164 だけでこの段差を形成することは難しく、かりに可能であったとしても上部電極 164 と上部電極端子 168 との接続状態が弱くなってしまい、切断してしまう危険がある。そこで、補助電極 172 を補助部材として用いて上部電極 164 と上部電極端子 168 とを接続させている。このようにすることで、圧電層 160 も上部電極 164 も補助電極 172 に支持された構造となり、所望の機械的強度を得ることができ、また上部電極 164 と上部電極端子 168 との接続を確実にすることが可能となる。

【0026】なお、圧電素子と振動板 176 のうちの圧電素子に直面する振動領域とが、アクチュエータ 106 において実際に振動する振動部である。また、アクチュエータ 106 に含まれる部材は、互いに焼成されることによって一体的に形成されることが好ましい。アクチュエータ 106 を一体的に形成することによって、アクチュエータ 106 の取り扱いが容易になる。さらに、基板 178 の強度を高めることによって振動特性が向上する。即ち、基板 178 の強度を高めることによって、アクチュエータ 106 の振動部のみが振動し、アクチュエータ 106 のうち振動部以外の部分が振動しない。また、アクチュエータ 106 の振動部以外の部分が振動しないためには、基板 178 の強度を高めるのに対して、アクチュエータ 106 の圧電素子を薄くかつ小さくし、振動板 176 を薄くすることによって達成できる。

【0027】圧電層 160 の材料としては、ジルコニウム酸チタン酸鉛 (PZT)、ジルコニウム酸チタン酸ランタン (PLZT) または鉛を使用しない鉛レス圧電膜を用いることが好ましく、基板 178 の材料としてジルコニアまたはアルミナを用いることが好ましい。また、振動板 176 には、基板 178 と同じ材料を用いることが好ましい。上部電極 164、下部電極 166、上部電極端子 168 および下部電極端子 170 は、導電性を有する材料、例えば金、銀、銅、プラチナ、アルミニウム、ニッケルなどの金属を用いることができる。

【0028】上述したように構成されるアクチュエータ

106は、液体を収容する容器に適用することができる。例えば、インクジェット記録装置に用いられるインクカートリッジやインクタンク、あるいは記録ヘッドを洗浄するための洗浄液を収容した容器などに装着することができる。

【0029】図1および図2に示されるアクチュエータ106は、液体容器の所定の場所に、キャピティ162を液体容器内に収容される液体と接触するように装着される。液体容器に液体が十分に収容されている場合には、キャピティ162内およびその外側は液体によって満たされている。一方、液体容器の液体が消費され、アクチュエータの装着位置以下まで液面が降下すると、キャピティ162内には液体は存在しないか、あるいはキャピティ162内にも液体が残存されその外側には気体が存在する状態となる。アクチュエータ106は、この状態の変化に起因する、少なくとも音響インピーダンスの相違を検出する。それによって、アクチュエータ106は、液体容器に液体が十分に収容されている状態であるか、あるいはある一定以上の液体が消費された状態であるかを検知することができる。さらに、アクチュエータ106は、液体容器内の液体の種類も検出することが可能である。

【0030】ここでアクチュエータによる液面検出の原理について説明する。

【0031】媒体の音響インピーダンスの変化を検出するには、媒体のインピーダンス特性またはアドミタンス特性を測定する。インピーダンス特性またはアドミタンス特性を測定する場合には、例えば伝送回路を利用することができる。伝送回路は、媒体に一定電圧を印加し、周波数を変えて媒体に流れる電流を測定する。または、伝送回路は、媒体に一定電流を供給し、周波数を変えて媒体に印加される電圧を測定する。伝送回路で測定された電流値または電圧値の変化は音響インピーダンスの変化を示す。また、電流値または電圧値が極大または極小となる周波数 f_m の変化も音響インピーダンスの変化を示す。

【0032】上記の方法とは別に、アクチュエータは、液体の音響インピーダンスの変化を共振周波数のみの変化を用いて検出することができる。液体の音響インピーダンスの変化を利用する方法として、アクチュエータの振動部が振動した後に振動部に残留する残留振動によって生ずる逆起電力を測定することによって共振周波数を検出する方法を用いる場合には、例えば圧電素子を利用することができる。圧電素子は、アクチュエータの振動部に残留する残留振動により逆起電力を発生する素子であり、アクチュエータの振動部の振幅によって逆起電力の大きさが変化する。従って、アクチュエータの振動部の振幅が大きいかほど検出がしやすくなる。また、アクチュエータの振動部における残留振動の周波数によって逆起電力の大きさが変化する周期が変わる。従って、アクチュ

エータの振動部の周波数は逆起電力の周波数に対応する。ここで、共振周波数は、アクチュエータの振動部と振動部に接する媒体との共振状態における周波数をいう。

【0033】共振周波数 f_s を得るために、振動部と媒体とが共振状態であるときの逆起電力測定によって得られた波形をフーリエ変換する。アクチュエータの振動は、一方向だけの変形ではなく、たわみや伸長等様々な変形をとまなうので、共振周波数 f_s を含め様々な周波数を有する。よって、圧電素子と媒体とが共振状態であるときの逆起電力の波形をフーリエ変換し、最も支配的な周波数成分を特定することで、共振周波数 f_s を判断する。

【0034】周波数 f_m は、媒体のアドミタンスが極大またはインピーダンスが極小であるときの周波数である。共振周波数 f_s とすると、周波数 f_m は、媒体の誘電損失または機械的損失などによって、共振周波数 f_s に対しわずかな誤差を生ずる。しかし、実測される周波数 f_m から共振周波数 f_s を導出することは手間がかかるため、一般には、周波数 f_m を共振周波数に代えて使用する。ここで、アクチュエータ106の出力を伝送回路に入力することで、アクチュエータ106は少なくとも音響インピーダンスを検出することができる。

【0035】媒体のインピーダンス特性またはアドミタンス特性を測定し周波数 f_m を測定する方法と、アクチュエータの振動部における残留振動振動によって生ずる逆起電力を測定することによって共振周波数 f_s を測定する方法と、によって特定される共振周波数に差がほとんど無いことが実験によって証明されている。

【0036】アクチュエータ106の振動領域は、振動板176のうち開口161によって決定されるキャピティ162を構成する部分である。液体容器内に液体が十分に収容されている場合には、キャピティ162内には、液体が満たされ、振動領域は液体容器内の液体と接触する。一方で、液体容器内に液体が充分にない場合には、振動領域は液体容器内のキャピティに残った液体と接するか、あるいは液体と接触せず、気体または真空と接触する。

【0037】本発明のアクチュエータ106にはキャピティ162が設けられ、それによって、アクチュエータ106の振動領域に液体容器内の液体が残るように設計できる。その理由は次の通りである。

【0038】アクチュエータの液体容器への取り付け位置や取り付け角度によっては、液体容器内の液体の液面がアクチュエータの装着位置よりも下方にあるにもかかわらず、アクチュエータの振動領域に液体が付着してしまう場合がある。振動領域における液体の有無だけでアクチュエータが液体の有無を検出している場合には、アクチュエータの振動領域に付着した液体が液体の有無の正確な検出を妨げる。たとえば、液面がアクチュエータ

の装着位置よりも下方にある状態のとき、キャリッジの往復移動などにより液体容器が揺動して液体が波うち、振動領域に液滴が付着してしまうと、アクチュエータは液体容器内に液体が充分にあるとの誤った判断をしてしまう。そこで、逆にそこに液体を残存した場合であっても液体の有無を正確に検出するように設計されたキャピティを積極的に設けることで、液体容器が揺動して液面が波立ったとしても、アクチュエータの誤動作を防止することができる。このように、キャピティを有するアクチュエータを用いることで、誤動作を防ぐことができる。

【0039】また、図2(E)に示すように、液体容器内に液体が無く、アクチュエータ106のキャピティ162に液体容器内の液体が残っている場合、液体の有無の閾値とする。すなわち、キャピティ162の周辺に液体が無く、この閾値よりキャピティ内の液体が少ない場合は、インク無しと判断し、キャピティ162の周辺に液体が有り、この閾値より液体が多い場合は、インク有りと判断する。例えば、アクチュエータ106を液体容器の側壁に装着した場合、液体容器内の液体がアクチュエータの装着位置よりも下にある場合をインク無しと判断し、液体容器内の液体がアクチュエータの装着位置より上にある場合をインク有りと判断する。このように閾値を設定することによって、キャピティ内のインクが乾燥してインクが無くなったときであってもインク無しと判断し、キャピティ内のインクが無くなったところにキャリッジの揺れなどで再度インクがキャピティに付着しても閾値を越えないので、インク無しと判断すること

$$f = s1 / (2 * \pi * (M * Cact))^{1/2}$$

で表される。ここで、Mは振動部のイナータンスMactと付加イナータンスM'との和である。Cactは振動部のコンプライアンスである。

【0043】図1(C)は、本実施例において、キャピティにインクが残存していないときのアクチュエータ106の断面図である。図2(A)および図2(B)は、 $Mact = M_{pzt} + M_{electrode1} + M_{electrode2} + M_{vib}$ と表される。ここで、Mpzは、振動部における圧電層160の厚さと圧電層160の密度との積を圧電層160の面積で除したものである。Melectrode1は、振動部における上部電極164の厚さと上部電極164の密度との積を上部電極164の面積で除したものである。Melectrode2は、振動部における下部電極166の厚さと下部電極166の密度との積を下部電極166の面積で除したものである。Mvibは、振動部における振動板176の厚さと振動板176の密度との積を振動板176の振動領域の面積で除したものである。ただし、Mactを振動部全体としての厚さ、密度および面積から算出することができるように、本実施例では、圧電層160、上部電極164、下部電極166および振動板176の振動領域のそれぞれの面積は、上述のような大小関係

ができる。

【0040】ここで、図1および図2を参照しながら逆起電力の測定による媒体とアクチュエータ106の振動部との共振周波数から液体容器内の液体の状態を検出する動作および原理について説明する。アクチュエータ106において、上部電極端子168および下部電極端子170を介して、それぞれ上部電極164および下部電極166に電圧を印加する。圧電層160のうち、上部電極164および下部電極166に挟まれた部分には電界が生じる。その電界によって、圧電層160は変形する。圧電層160が変形することによって振動板176のうちの振動領域がたわみ振動する。圧電層160が変形した後しばらくは、たわみ振動がアクチュエータ106の振動部に残存する。

【0041】残留振動は、アクチュエータ106の振動部と媒体との自由振動である。従って、圧電層160に印加する電圧をパルス波あるいは矩形波とすることで、電圧を印加した後に振動部と媒体との共振状態を容易に得ることができる。残留振動は、アクチュエータ106の振動部を振動させるため、圧電層160をも変形する。従って、圧電層160は逆起電力を発生する。その逆起電力は、上部電極164、下部電極166、上部電極端子168および下部電極端子170を介して検出される。検出された逆起電力によって、共振周波数が特定できるため、液体容器内の液体の状態を検出することができる。

【0042】一般に、共振周波数f sは、

$$(式1)$$

キャピティにインクが残存していないときのアクチュエータ106の振動部およびキャピティ162の等価回路である。

【0044】Mactは、振動部の厚さと振動部の密度との積を振動部の面積で除したものであり、さらに詳細には、図2(A)に示すように、

$$(式2)$$

有するものの、相互の面積の差は微小であることが好ましい。また、本実施例において、圧電層160、上部電極164および下部電極166においては、それらの主要部である円形部分以外の部分は、主要部に対して無視できるほど微小であることが好ましい。従って、アクチュエータ106において、Mactは、上部電極164、下部電極166、圧電層160および振動板176のうちの振動領域のそれぞれのイナータンスの和である。また、コンプライアンスCactは、上部電極164、下部電極166、圧電層160および振動板176のうちの振動領域によって形成される部分のコンプライアンスである。

【0045】尚、図2(A)、図2(B)、図2(D)、図2(F)は、アクチュエータ106の振動部およびキ

キャピティ162の等価回路を示すが、これらの等価回路において、Cactはアクチュエータ106の振動部のコンプライアンスを示す。Cpzt、Celectrodel、Celectrode2およびCvibはそれぞれ振動部における圧電層16

$$1/Cact = (1/Cpzt) + (1/Celectrodel) + (1/Celectrode2) + (1/Cvib) \quad (式3)$$

式2および式3より、図2 (A)は、図2 (B)のように表すこともできる。

【0047】コンプライアンスCactは、振動部の単位面積に圧力をかけたときの変形によって媒体を受容できる体積を表す。また、コンプライアンスCactは、変形のし易さを表すといってもよい。

【0048】図2 (C)は、液体容器に液体が十分に収

$$M'_{\max} = (\pi * \rho / (2 * k^3)) * (2 * (2 * k * a)^3 / (3 * \pi)) / (\pi * a^2)^2 \quad (式4)$$

(aは振動部の半径、 ρ は媒体の密度、kは波数である。)

【0050】で表される。尚、式4は、アクチュエータ106の振動領域が半径aの円形である場合に成立する。付加イナータンスM'は、振動部の付近にある媒体の作用によって、振動部の質量が見かけ上増加していることを示す量である。式4からわかるように、M' maxは振動部の半径aと、媒体の密度 ρ とによって大きく変化する。

【0051】波数kは、 $k = 2 * \pi * \text{fact} / c$ (式5)

(factは液体が触れていないときの振動部の共振周波数である。cは媒体中を伝播する音響の速度である。)

【0052】で表される。

【0053】図2 (D)は、液体容器に液体が十分に収容され、アクチュエータ106の振動領域の周辺に液体が満たされている図2 (C)の場合のアクチュエータ106の振動部およびキャピティ162の等価回路を示す。

【0054】図2 (E)は、液体容器の液体が消費され、アクチュエータ106の振動領域の周辺に液体が無いもの、アクチュエータ106のキャピティ162内には液体が残存している場合のアクチュエータ106の断面図を示す。式4は、例えば、液体容器に液体が満たされている場合に、インクの密度 ρ などから決定される最大のイナータンスM' maxを表す式である。一方、液体容器内の液体が消費され、キャピティ162内に液体が残留しつつアクチュエータ106の振動領域の周辺にある液体が気体または真空になった場合には、

【0055】M' = $\rho * t / S$ (式6)

と表せる。tは、振動にかかわる媒体の厚さである。Sは、アクチュエータ106の振動領域の面積である。この振動領域が半径aの円形の場合は、 $S = \pi * a^2$ である。従って、付加イナータンスM'は、液体容器に液体が十分に収容され、アクチュエータ106の振動領域の周辺に液体が満たされている場合には、式4に従う。一

方、上部電極164、下部電極166および振動板176のコンプライアンスを示す。Cactは、以下の式3で表される。

【0046】

容され、アクチュエータ106の振動領域の周辺に液体が満たされている場合のアクチュエータ106の断面図を示す。図2 (C)のM' maxは、液体容器に液体が十分に収容され、アクチュエータ106の振動領域の周辺に液体が満たされている場合の付加イナータンスの最大値を表す。M' maxは、

【0049】

方で、液体が消費され、キャピティ162内に液体が残留しつつアクチュエータ106の振動領域の周辺にある液体が気体または真空になった場合には、式6に従う。

【0056】ここで、図2 (E)のように、液体容器の液体が消費され、アクチュエータ106の振動領域の周辺に液体が無いもの、アクチュエータ106のキャピティ162内には液体が残存している場合の付加イナータンスM'を便宜的にM' cavとし、アクチュエータ106の振動領域の周辺に液体が満たされている場合の付加イナータンスM' maxと区別する。

【0057】図2 (F)は、液体容器の液体が消費され、アクチュエータ106の振動領域の周辺に液体が無いもの、アクチュエータ106のキャピティ162内には液体が残存している図2 (E)の場合のアクチュエータ106の振動部およびキャピティ162の等価回路を示す。

【0058】ここで、媒体の状態に係るパラメータは、式6において、媒体の密度 ρ および媒体の厚さtである。液体容器内に液体が十分に収容されている場合は、アクチュエータ106の振動部に液体が接触し、液体容器内に液体が十分に収容されていない場合は、キャピティ内部に液体が残存するか、もしくはアクチュエータ106の振動部に気体または真空が接触する。アクチュエータ106の周辺の液体が消費され、図2 (C)のM' maxから図2 (E)のM' cavへ移行する過程における付加イナータンスをM' varとすると、液体容器内の液体の収容状態によって、媒体の密度 ρ や媒体の厚さtが変化するため、付加イナータンスM' varが変化し、共振周波数f sも変化するようになる。従って、共振周波数f sを特定することによって、液体容器内の液体の有無を検出することができる。式6を用いてM' cavを表すと、式6のtにキャピティの深さdを代入し、

【0059】

$$M'_{\text{cav}} = \rho * d / S \quad (式7)$$

となる。

【0060】また、媒体が互いに種類の異なる液体であ

っても、組成の違いによって密度 ρ が異なるため、付加イナータンス M' が変化し、共振周波数 f_s も変化する。従って、共振周波数 f_s を特定することで、液体の種類を検出できる。尚、アクチュエータ 106 の振動部にインクまたは空気のいずれか一方のみが接触し、混在していない場合には、式 4 によって計算しても、 M' の相違を検出できる。

【0061】図 3 (A) は、インクタンク内のインクの量とインクおよび振動部の共振周波数 f_s との関係を示すグラフである。ここでは液体の 1 例としてインクについて説明する。縦軸は、共振周波数 f_s を示し、横軸は、インク量を示す。インク組成が一定であるとき、インク残量の低下に伴い、共振周波数 f_s は、上昇する。

【0062】インク容器にインクが十分に収容され、アクチュエータ 106 の振動領域の周辺にインクが満たされている場合には、その最大付加イナータンス M'_{\max} は式 1 に表わされる値となる。一方で、インクが消費され、キャパシティ 162 内に液体が残留しつつアクチュエータ 106 の振動領域の周辺にインクが満たされていないときには、付加イナータンス M'_{var} は、媒体の厚さ t に基づいて式 6 によって算出される。式 6 中の t は振動にかかわる媒体の厚さであるから、アクチュエータ 106 のキャパシティ 162 の d (図 1 (B) 参照) を小さく、即ち、基板 178 を十分に薄くすることによって、インクが徐々に消費されていく過程を検出することもできる (図 2 (C) 参照)。ここで、 t_{ink} は振動にかかわるインクの厚さとし、 $t_{\text{ink-max}}$ は M'_{\max} における t_{ink} とする。例えば、インクカートリッジの底面にアクチュエータ 106 をインクの液面に対してほぼ水平に配備する。インクが消費され、インクの液面がアクチュエータ 106 から t の高さ以下に達すると、式 6 より M'_{var} が徐々に変化し、式 1 により共振周波数 f_s が徐々に変化する。従って、インクの液面が t の範囲内にある限り、アクチュエータ 106 はインクの消費状態を徐々に検出することができる。

【0063】また、アクチュエータ 106 の振動領域を $M' = M'_{\text{air}} + M'_{\text{ink}} = \rho_{\text{air}} * t_{\text{air}} / S + \rho_{\text{ink}} * t_{\text{ink}} / S$ (式 8) となる。ここで、 M'_{air} は空気のイナータンスであり、 M'_{ink} はインクのイナータンスである。 ρ_{air} は空気の密度であり、 ρ_{ink} はインクの密度である。 t_{air} は振動にかかわる空気の厚さであり、 t_{ink} は振動にかかわるインクの厚さである。アクチュエータ 106 の振動領域周辺における振動にかかわる媒体のうち、液体が減少して気体が増加するに従い、アクチュエータ 106 がインクの液面に対しほぼ水平に配備されている場合には、 t_{air} が増加し、 t_{ink} が減少する。それによって、 M'_{var} が徐々に減少し、共振周波数が徐々に増加する。よって、インクタンク内に残存しているインクの量またはインクの消費量を検出することができる。尚、式 7 において液体の密度のみの式となっているのは、液体

大きくまたは長くし、かつ縦に配置することによってインクの消費による液面の位置にしたがって、式 6 中の S が変化する。従って、アクチュエータ 106 はインクが徐々に消費されていく過程を検出することもできる。例えば、インクカートリッジの側壁にアクチュエータ 106 をインクの液面に対してほぼ垂直に配備する。インクが消費され、インクの液面がアクチュエータ 106 の振動領域に達すると、水位の低下に伴い付加イナータンス M' が減少するので、式 1 により共振周波数 f_s が徐々に増加する。従って、インクの液面が、キャパシティ 162 の径 $2a$ (図 2 (C) 参照) の範囲内にある限り、アクチュエータ 106 はインクの消費状態を徐々に検出することができる。

【0064】図 3 (A) の曲線 X は、アクチュエータ 106 のキャパシティ 162 を十分に浅くした場合や、アクチュエータ 106 の振動領域を十分に大きくまたは長くした場合のインクタンク内に収容されたインクの量とインクおよび振動部の共振周波数 f_s との関係を表わしている。インクタンク内のインクの量が減少するとともに、インクおよび振動部の共振周波数 f_s が徐々に変化していく様子が理解できる。

【0065】より詳細には、インクが徐々に消費されていく過程を検出することができる場合には、アクチュエータ 106 の振動領域の周辺において、互いに密度が異なる液体と気体とがともに存在し、かつ振動にかかわる場合である。インクが徐々に消費されていくに従って、アクチュエータ 106 の振動領域周辺において振動にかかわる媒体は、液体が減少する一方で気体が増加する。例えば、アクチュエータ 106 をインクの液面に対して水平に配備した場合であって、 $t_{\text{ink}} > t_{\text{ink-max}}$ より小さいときには、アクチュエータ 106 の振動にかかわる媒体はインクと気体との両方を含む。したがって、アクチュエータ 106 の振動領域の面積 S とすると、式 4 の M'_{\max} 以下になった状態をインクと気体の付加質量で表すと、

$$\text{【0066】} \quad M' = M'_{\text{air}} + M'_{\text{ink}} = \rho_{\text{air}} * t_{\text{air}} / S + \rho_{\text{ink}} * t_{\text{ink}} / S \quad (\text{式 8})$$

の密度に対して、空気の密度が無視できるほど小さい場合を想定しているからである。

【0067】アクチュエータ 106 がインクの液面に対しほぼ垂直に配備されている場合には、アクチュエータ 106 の振動領域のうち、アクチュエータ 106 の振動にかかわる媒体がインクのみ領域と、アクチュエータ 106 の振動にかかわる媒体が気体の領域との並列の等価回路 (図示せず) と考えられる。アクチュエータ 106 の振動にかかわる媒体がインクのみ領域の面積を S_{ink} とし、アクチュエータ 106 の振動にかかわる媒体が気体のみ領域の面積を S_{air} とすると、

$$\text{【0068】}$$

$$1/M' = 1/M'_{air} + 1/M'_{ink} = S_{air}/(\rho_{air} \cdot t_{air}) + S_{ink}/(\rho_{ink} \cdot t_{ink}) \quad (式9)$$

となる。

【0069】尚、式9は、アクチュエータ106のキャピティにインクが保持されない場合に適用される。アクチュエータ106のキャピティにインクが保持される場合については、式7、式8および式9によって計算することができる。

【0070】一方、基板178が厚く、即ち、キャピティ162の深さdが深く、dが媒体の厚さt_{ink}-maxに比較的近い場合や、液体容器の高さに比して振動領域が非常に小さいアクチュエータを用いる場合には、実際上はインクが徐々に減少する過程を検出するというよりはインクの液面がアクチュエータの装着位置より上位置か下位置かを検出することになる。換言すると、アクチュエータの振動領域におけるインクの有無を検出することになる。例えば、図3(A)の曲線Yは、小さい円形の振動領域の場合におけるインクタンク内のインクの量とインクおよび振動部の共振周波数f_sとの関係を示す。インクタンク内のインクの液面がアクチュエータの装着位置を通過する前後におけるインク量Qの間で、インクおよび振動部の共振周波数f_sが激しく変化している様子が示される。このことから、インクタンク内にインクが所定量残存しているか否かを検出することができる。

【0071】アクチュエータ106を用いて液体の有無を検出する方法は、振動板176が、液体と直接接触すること、インクの有無を検出するので、インクの消費量をソフトウェアによって計算する方法に比べ、検出精度が高い。更に、電極を用いて、導電性によりインクの有無を検出する方法は、液体容器への取付位置及びインクの種類によって影響されるが、アクチュエータ106を用いて液体の有無を検出する方法は、液体容器への取付位置及びインクの種類によって、影響されない。更に、単一のアクチュエータ106を用いて、発振と液体の有無の検出の双方をすることができるので、発振と液体の有無の検出とを異なったセンサを用いて実施する方法と比較して液体容器に取付けるセンサの数を減少することができる。したがって、液体容器を安価に製造できる。更に、圧電層160の振動周波数を非共振領域に設定することで、アクチュエータ106の動作中に発生する音を静かにすることができる。

【0072】図3(B)は、図3(A)の曲線Yにおけるインクの密度とインクおよび振動部の共振周波数f_sとの関係を示す。液体の例としてインクを挙げている。図3(B)に示すように、インク密度が高くなると、付加イナータンスが大きくなるので共振周波数f_sが低下する。すなわち、インクの種類によって共振周波数f_sが異なる。したがって共振周波数f_sを測定することによって、インクを再充填する際に、密度の異なったインクが混入されていないか確認することができる。

【0073】つまり、互いに種類の異なるインクを収容するインクタンクを識別できる。

【0074】続いて、液体容器内の液体が空の状態であってもアクチュエータ106のキャピティ162内に液体が残存するようにキャピティのサイズと形状を設定した時の、液体の状態を正確に検出できる条件を詳述する。アクチュエータ106は、キャピティ162内に液体が満たされている場合に液体の状態を検出できれば、キャピティ162内に液体が満たされていない場合であっても液体の状態を検出できる。

【0075】共振周波数f_sは、イナータンスMの関数である。イナータンスMは、振動部のイナータンスM_{act}と付加イナータンスM'との和である。ここで、付加イナータンスM'が液体の状態と関係する。付加イナータンスM'は、振動部の付近にある媒体の作用によって振動部の質量が見かけ上増加していることを示す量である。即ち、振動部の振動によって見かけ上媒体を吸収することによる振動部の質量の増加分をいう。

【0076】従って、M' cavが式4におけるM' maxよりも大きい場合には、見かけ上吸収する媒体は全てキャピティ162内に残存する液体である。よって、液体容器内に液体が満たされている状態と同じである。この場合にはM'が変化しないので、共振周波数f_sも変化しない。従って、アクチュエータ106は、液体容器内の液体の状態を検出できないことになる。

【0077】一方、M' cavが式4におけるM' maxよりも小さい場合には、見かけ上吸収する媒体はキャピティ162内に残存する液体および液体容器内の気体または真空である。このときには液体容器内に液体が満たされている状態とは異なりM'が変化するので、共振周波数f_sが変化する。従って、アクチュエータ106は、液体容器内の液体の状態を検出できる。

【0078】即ち、液体容器内の液体が空の状態、アクチュエータ106のキャピティ162内に液体が残存する場合に、アクチュエータ106が液体の状態を正確に検出できる条件は、M' cavがM' maxよりも小さいことである。尚、アクチュエータ106が液体の状態を正確に検出できる条件M' max > M' cavは、キャピティ162の形状にかかわらず。

【0079】ここで、M' cavは、キャピティ162の容量とほぼ等しい容量の液体の質量である。従って、M' max > M' cavの不等式から、アクチュエータ106が液体の状態を正確に検出できる条件は、キャピティ162の容量の条件として表すことができる。例えば、円形状のキャピティ162の開口161の半径をaとし、およびキャピティ162の深さをdとすると、

$$【0080】M' max > \rho \cdot \pi \cdot d / \pi a^2 \quad (式10)$$

である。式10を展開すると

【0081】 $a/d > 3\pi/8$ (式11)

という条件が求められる。尚、式10、式11は、キャピティ162の形状が円形の場合に限り成立する。円形でない場合の M'_{max} の式を用い、式10中の πa^2 をその面積に置き換えて計算すれば、キャピティの幅および長さ等のディメンジョンと深さの関係が導き出せる。

【0082】従って、式11を満たす開口161の半径 a およびキャピティ162の深さ d であるキャピティ162を有するアクチュエータ106であれば、液体容器内の液体が空の状態であって、かつキャピティ162内に液体が残存する場合であっても、誤作動することなく液体の状態を検出できる。

【0083】付加イナータンス M' は音響インピーダンス特性にも影響するので、残留振動によりアクチュエータ106に発生する逆起電力を測定する方法は、少なくとも音響インピーダンスの変化を検出しているともいえる。

【0084】また、本実施例によれば、アクチュエータ106が振動を発生してその後の残留振動によりアクチュエータ106に発生する逆起電力を測定している。しかし、アクチュエータ106の振動部が駆動電圧による自らの振動によって液体に振動を与えることは必ずしも必要ではない。即ち、振動部が自ら発振しなくても、それと接触しているある範囲の液体と共に振動すること、圧電層160がたわみ変形する。この残留振動が圧電層160に逆起電力電圧を発生させ、上部電極164および下部電極166にその逆起電力電圧を伝達する。この現象を利用することで媒体の状態を検出してよい。例えば、インクジェット記録装置において、印字時における印字ヘッドの走査によるキャリッジの往復運動による振動によって発生するアクチュエータの振動部の周囲の振動を利用してインクタンクまたはその内部のインクの状態を検出してよい。

【0085】図4(A)および図4(B)は、アクチュエータ106を振動させた後の、アクチュエータ106の残留振動の波形と残留振動の測定方法とを示す。インクカートリッジ内のアクチュエータ106の装着位置レベルにおけるインク水位の上下は、アクチュエータ106が発振した後の残留振動の周波数変化や、振幅の変化によって検出することができる。図4(A)および図4(B)において、縦軸はアクチュエータ106の残留振動によって発生した逆起電力の電圧を示し、横軸は時間を示す。アクチュエータ106の残留振動によって、図4(A)および図4(B)に示すように電圧のアナログ信号の波形が発生する。次に、アナログ信号を、信号の周波数に対応するデジタル数値に変換する。

【0086】図4(A)および図4(B)に示した例においては、アナログ信号の4パルス目から8パルス目までの4個のパルスが生じる時間を計測することによって、インクの有無を検出する。

【0087】より詳細には、アクチュエータ106が発振した後、予め設定された所定の基準電圧を低電圧側から高電圧側へ横切る回数をカウントする。デジタル信号を4カウントから8カウントまでの間をHighとし、所定のクロックパルスによって4カウントから8カウントまでの時間を計測する。

【0088】図4(A)はアクチュエータ106の装着位置レベルよりも上位にインク液面があるときの波形である。一方、図4(B)はアクチュエータ106の装着位置レベルにおいてインクが無いときの波形である。図4(A)と図4(B)とを比較すると、図4(A)の方が図4(B)よりも4カウントから8カウントまでの時間が長いことがわかる。換言すると、インクの有無によって4カウントから8カウントまでの時間が異なる。この時間の相違を利用して、インクの消費状態を検出することができる。アナログ波形の4カウント目から数えるのは、アクチュエータ106の振動が安定してから計測をはじめるためである。4カウント目からとしたのは単なる一例であって、任意のカウントから数えてよい。ここでは、4カウント目から8カウント目までの信号を検出し、所定のクロックパルスによって4カウント目から8カウント目までの時間を測定する。それによって、共振周波数を求める。クロックパルスは、インクカートリッジに取り付けられる半導体記憶装置等を制御するためのクロックと等しいクロックのパルスであることが好ましい。尚、8カウント目までの時間を測定する必要は無く、任意のカウントまで数えてよい。図4においては、4カウント目から8カウント目までの時間を測定しているが周波数を検出する回路構成にしたがって、異なるカウント間隔内の時間を検出してよい。

【0089】例えば、インクの品質が安定してピークの振幅の変動が小さい場合には、検出の速度を上げるために4カウント目から6カウント目までの時間を検出することにより共振周波数を求めてよい。また、インクの品質が不安定でパルスの振幅の変動が大きい場合には、残留振動を正確に検出するために4カウント目から12カウント目までの時間を検出してよい。

【0090】また、他の実施例として所定期間内における逆起電力の電圧波形の波数を数えてよい（図示せず）。この方法によっても共振周波数を求めることができる。より詳細には、アクチュエータ106が発振した後、所定期間だけデジタル信号をHighとし、所定の基準電圧を低電圧側から高電圧側へ横切る回数をカウントする。そのカウント数を計測することによってインクの有無を検出できるのである。

【0091】さらに、図4(A)および図4(B)を比較して分かるように、インクがインクカートリッジ内に満たされている場合とインクがインクカートリッジ内に無い場合とでは、逆起電力波形の振幅が異なる。従って、共振周波数を求めることなく、逆起電力波形の振幅を測定

することによっても、インクカートリッジ内のインクの消費状態を検出してもよい。より詳細には、例えば、図4(A)の逆起電力波形の頂点と図4(B)の逆起電力波形の頂点との間に基準電圧を設定する。アクチュエータ106が発振した後、所定時間デジタル信号をHighとし、逆起電力波形が基準電圧を横切った場合には、インクが無いと判断する。逆起電力波形が基準電圧を横切らない場合には、インクが有ると判断する。

【0092】図5は、アクチュエータ106の製造方法を示す。複数のアクチュエータ106(図5の例では4個)が一体に形成されている。図5に示した複数のアクチュエータの一体成形物を、それぞれのアクチュエータ106において切断することにより、図6に示すアクチュエータ106を製造する。図5に示す一体成形された複数のアクチュエータ106のそれぞれの圧電素子が円形である場合、一体成形物をそれぞれのアクチュエータ106において切断することにより、図1に示すアクチュエータ106を製造することができる。複数のアクチュエータ106を一体に形成することにより、複数のアクチュエータ106を同時に効率的に製造することができる、運搬時の取り扱いが容易となる。

【0093】アクチュエータ106は、基板又は振動板176、基板178、弾性波発生手段又は圧電素子174、端子形成部材又は上部電極端子168、及び端子形成部材又は下部電極端子170を有する。圧電素子174は、圧電振動板又は圧電層160、上電極又は上部電極164、及び下部電極又は下部電極166を含む。基板178の上面に振動板176が、形成され、振動板176の上面に下部電極166が形成されている。下部電極166の上面には、圧電層160が形成され、圧電層160の上面に、上部電極164が、形成されている。したがって、圧電層160の主要部は、上部電極164の主要部及び下部電極166の主要部によって、上下から挟まれるように形成されている。

【0094】振動板176上に複数(図5の例では4個)の圧電素子174が形成されている。振動板176の表面に下部電極166が形成され、下部電極166の表面に圧電層160が形成され、圧電層160の上面に上部電極164が形成される。上部電極164及び下部電極166の端部に上部電極端子168及び下部電極端子170が形成される。4個のアクチュエータ106は、それぞれ別々に切断されて個別に使用される。

【0095】図6は、圧電素子が矩形的アクチュエータ106の一部分の断面を示す。

【0096】図7は、図6に示したアクチュエータ106の全体の断面を示す。基板178の圧電素子174と対向する面には、貫通孔178aが形成されている。貫通孔178aは振動板176によって封止されている。振動板176はアルミナや酸化シリコン等の電気絶縁性を備え、かつ弾性変形可能な材料によって形成されて

いる。貫通孔178aと対向するように、圧電素子174が振動板176上に形成されている。下部電極166は貫通孔178aの領域から一方、図7では左方に延びるように振動板176の表面に形成されている。上部電極164は貫通孔178aの領域から下部電極とは反対の方向に、図7では右方に延びるように圧電層160の表面に形成されている。上部電極端子168及び下部電極端子170は、それぞれ補助電極172及び下部電極166の上面に形成されている。下部電極端子170は下部電極166と電気的に接触し、上部電極端子168は補助電極172を介して上部電極164と電気的に接触して、圧電素子とアクチュエータ106の外部との間の信号の受け渡しをする。上部電極端子168及び下部電極端子170は、電極と圧電層とを合わせた圧電素子の高さ以上の高さを有する。

【0097】図8は、図5に示したアクチュエータ106の製造方法を示す。まず、グリーンシート940にプレスあるいはレーザー加工等を用いて貫通孔940aを穿孔する。グリーンシート940は焼成後に基板178となる。グリーンシート940はセラミック等の材料で形成される。次に、グリーンシート940の表面にグリーンシート941を積層する。グリーンシート941は、焼成後に振動板176となる。グリーンシート941は、酸化ジルコニア等の材料で形成される。次に、グリーンシート941の表面に導電層942、圧電層160、導電層944を圧入印刷等の方法で順次形成する。導電層942は、後に下部電極166となり、導電層944は、後に上部電極164となる。次に、形成されたグリーンシート940、グリーンシート941、導電層942、圧電層160、及び導電層944を乾燥して焼成する。スペーサ部材947、948は、上部電極端子168と下部電極端子170の高さを底上げして圧電素子より高くする。スペーサ部材947、948は、グリーンシート940、941と同材料を印刷、あるいはグリーンシートを積層して形成する。このスペーサ部材947、948により貴金属である上部電極端子168及び下部電極端子170の材料が少なく済む上に、上部電極端子168及び下部電極端子170の厚みを薄くできるので、上部電極端子168及び下部電極端子170を精度高く印刷でき、さらに安定した高さとすることができる。

【0098】導電層942の形成時に導電層944との接続部944'及びスペーサ部材947及び948を同時に形成すると、上部電極端子168及び下部電極端子170を容易に形成したり、強固に固定することができる。最後に、導電層942及び導電層944の端部領域に、上部電極端子168及び下部電極端子170を形成する。上部電極端子168及び下部電極端子170を形成する際、上部電極端子168及び下部電極端子170が、圧電層160に電気的に接続されるように形成す

る。

【0099】図9は、本発明が適用されるインクカートリッジのさらに他の実施形態を示す。図9(A)は、本実施形態によるインクカートリッジの底部の断面図である。本実施形態のインクカートリッジは、インクを収容する容器1の底面1aに貫通孔1cを有する。貫通孔1cの底部はアクチュエータ650によって塞がれ、インク溜部を形成する。

【0100】図9(B)は、図9(A)に示したアクチュエータ650及び貫通孔1cの詳細な断面図を示す。図9(C)は、図9(B)に示したアクチュエータ650及び貫通孔1cの平面図を示す。アクチュエータ650は、振動板72および振動板72に固定された圧電素子73とを有する。振動板72及び基板71を介して圧電素子73が貫通孔1cに対向するように、アクチュエータ650は、容器1の底面に固定される。振動板72は、弾性変形可能で耐インク性を備える。

【0101】容器1のインク量に依って、圧電素子73及び振動板72の残留振動によって発生する逆起電力の振幅及び周波数に変化する。アクチュエータ650に対向する位置に貫通孔1cが形成されていて、最小限の一定量のインクが貫通孔1cに確保される。したがって、貫通孔1cに確保されるインク量により決まるアクチュエータ650の振動の特性を予め測定しておくことにより、容器1のインクエンドを確実に検出することができる。

【0102】図10は貫通孔1cの他の実施形態を示す。図10(A)、(B)、及び(C)のそれぞれにおいて、左側の図は、貫通孔1cにインクKが無い状態を示し、右側の図は、貫通孔1cにインクKが残った状態を示す。図9の実施形態においては、貫通孔1cの側面は垂直な壁として形成されている。図10(A)においては、貫通孔1cは、側面1dが上下方向に斜めであり外側に拡大して開いている。図10(B)においては、段差部1e及び1fが、貫通孔1cの側面に形成されている。上方にある段差部1fが、下方にある段差部1eより広くなっている。図10(C)においては、貫通孔1cは、インクKを排出しやすい方向、すなわちインク供給口2の方向へ延びる溝1gを有する。

【0103】図10(A)~(C)に示した貫通孔1cの形状によれば、インク溜部のインクKの量を少なくできる。従って、図1および図2で説明したM' cavをM' maxと比較して小さくすることができるので、インクエンド時におけるアクチュエータ650の振動特性を、容器1に印刷可能な量のインクKが残っている場合と大きく異ならせることができるので、インクエンドをより確実に検出することができる。

【0104】図11はアクチュエータの他の実施形態を示す斜視図である。アクチュエータ660は、アクチュエータ660を構成する基板または取付プレート78の

貫通孔1cよりも外側にバックイン76を有する。アクチュエータ660の外周にはカシメ孔77が形成されている。アクチュエータ660は、カシメ孔77を介してカシメにより容器1に固定される。

【0105】図12(A)、(B)は、アクチュエータの更に他の実施形態を示す斜視図である。本実施形態においては、アクチュエータ670は、凹部形成基板80および圧電素子82を備える。凹部形成基板80の一方の面には凹部81がエッチング等の手法により形成され、他方の面には圧電素子82が取り付けられる。凹部形成基板80のうち、凹部81の底部が振動領域として作用する。従って、アクチュエータ670の振動領域は凹部81の周縁によって規定される。また、アクチュエータ670は、図1の実施例によるアクチュエータ106のうち、基板178および振動板176が一体として形成された構造と類似する。従って、インクカートリッジを製造する際に製造工程を短縮することができ、コストを低減させる。アクチュエータ670は、容器1に設けられた貫通孔1cに埋め込み可能なサイズである。それによって、凹部81がキャピリティとしても作用することができる。尚、図1の実施例によるアクチュエータ106を、図12の実施例によるアクチュエータ670と同様に貫通孔1cに埋め込み可能なように形成してもよい。

【0106】図13は、アクチュエータ106を取り付けモジュール体100として一体形成した構成を示す斜視図である。モジュール体100はインクカートリッジの容器1の所定箇所に装着される。モジュール体100は、インク液中の少なくとも音響インピーダンスの変化を検出することにより、容器1内の液体の消費状態を検知するように構成されている。本実施形態のモジュール体100は、容器1にアクチュエータ106を取り付けるための液体容器取付部101を有する。液体容器取付部101は、平面がほぼ矩形状の基台102上に駆動信号により発振するアクチュエータ106を収容した円柱部116を載せた構造になっている。モジュール体100が、インクカートリッジに装着されたときに、モジュール体100のアクチュエータ106が外部から接触できないように構成されているので、アクチュエータ106を外部の接触から保護することができる。なお、円柱部116の先端側エッジは丸みが付けられていて、インクカートリッジに形成された孔へ装着する際に嵌めやすくなっている。

【0107】図14は、図13に示したモジュール体100の構成を示す分解図である。モジュール体100は、樹脂からなる液体容器取付部101と、プレート110および凹部113を有する圧電装置装着部105とを含む。さらに、モジュール体100は、リードワイヤ104a及び104b、アクチュエータ106、およびフィルム108を有する。好ましくは、プレート110

は、ステンレス又はステンレス合金等の錆びにくい材料から形成される。液体容器取付部101に含まれる円柱部116および基台102は、リードワイヤ104a及び104bを収容できるよう中心部に開口部114が形成され、アクチュエータ106、フィルム108、及びプレート110を収容できるように凹部113が形成される。アクチュエータ106はプレート110にフィルム108を介して接合され、プレート110およびアクチュエータ106は液体容器取付部101に固定される。従って、リードワイヤ104a及び104b、アクチュエータ106、フィルム108およびプレート110は、液体容器取付部101に一体として取り付けられる。リードワイヤ104a及び104bは、それぞれアクチュエータ106の上部電極及び下部電極と結合して圧電層に駆動信号を伝達し、一方、アクチュエータ106が検出した共振周波数の信号を記録装置等へ伝達する。アクチュエータ106は、リードワイヤ104a及び104bから伝達された駆動信号に基づいて一時的に発振する。アクチュエータ106は発振後に残留振動し、その振動によって逆起電力を発生させる。このとき、逆起電力波形の振動周期を検出することによって、液体容器内の液体の消費状態に対応した共振周波数を検出することができる。フィルム108は、アクチュエータ106とプレート110とを接合してアクチュエータを液密にする。フィルム108は、ポリオレフィン等によって形成し、熱融着で接合することが好ましい。フィルム108は、アクチュエータ106とプレート110とを接合してアクチュエータを液密にする。フィルム108は、ポリオレフィンによって形成し、熱融着で接合することが好ましい。アクチュエータ106とプレート110とをフィルム108によって面状に接合して固定することにより、接合の場所によるばらつきが無くなり、振動部以外の部分が振動しない。したがって、アクチュエータ106をプレート110に接合する前と後における共振周波数の変化が小さい。

【0108】プレート110は円形状であり、基台102の開口部114は円筒状に形成されている。アクチュエータ106及びフィルム108は矩形形状に形成されている。リードワイヤ104、アクチュエータ106、フィルム108、及びプレート110は、基台102に対して着脱可能としてもよい。基台102、リードワイヤ104、アクチュエータ106、フィルム108、及びプレート110は、モジュール体100の中心軸に対して対称に配置されている。更に、基台102、アクチュエータ106、フィルム108、及びプレート110の中心は、モジュール体100のほぼ中心軸上に配置されている。

【0109】基台102の開口部114の面積は、アクチュエータ106の振動領域の面積よりも大きく形成されている。プレート110の中心でアクチュエータ10

6の振動部に直面する位置には、貫通孔112が形成されている。図1および図2に示したようにアクチュエータ106にはキャビティ162が形成され、貫通孔112とキャビティ162は、共にインク溜部を形成する。プレート110の厚さは、残留インクの影響を少なくするために貫通孔112の径に比べて小さいことが好ましい。例えば貫通孔112の深さはその径の3分の1以下の大きさであることが好ましい。貫通孔112は、モジュール体100の中心軸に対して対称なほぼ真円の形状である。また貫通孔112の面積は、アクチュエータ106のキャビティ162の開口面積よりも大きい。貫通孔112の断面の周縁はテーパー形状であっても良い。ステップ形状でもよい。モジュール体100は、貫通孔112が容器1の内側へ向くように容器1の側部、上部、又は底部に装着される。インクが消費されアクチュエータ106周辺のインクがなくなると、アクチュエータ106の共振周波数が大きく変化するので、インクの水位変化を検出することができる。

【0110】図15は、モジュール体の他の実施形態を示す斜視図である。本実施形態のモジュール体400は、液体容器取付部401に圧電装置装着部405が形成されている。液体容器取付部401は、平面がほぼ角丸の正方形上の基台402上に円柱状の円柱部403が形成されている。更に、圧電装置装着部405は、円柱部403上に立てられた板状要素406および凹部413を含む。板状要素406の側面に設けられた凹部413には、アクチュエータ106が配置される。なお、板状要素406の先端は所定角度に面取りされていて、インクカートリッジに形成された孔へ装着する際に嵌めやすくなっている。

【0111】図16は、図15に示したモジュール体400の構成を示す分解斜視図である。図13に示したモジュール体100と同様に、モジュール体400は、液体容器取付部401および圧電装置装着部405を含む。液体容器取付部401は基台402および円柱部403を有し、圧電装置装着部405は板状要素406および凹部413を有する。アクチュエータ106は、プレート410に接合されて凹部413に固定される。モジュール体400は、リードワイヤ404a及び404b、アクチュエータ106、及びフィルム408をさらに有する。

【0112】本実施形態によれば、プレート410は矩形形状であり、板状要素406に設けられた開口部414は矩形形状に形成されている。リードワイヤ404a及び404b、アクチュエータ106、フィルム408、及びプレート410は基台402に対して着脱可能として構成してもよい。アクチュエータ106、フィルム408、及びプレート410は、開口部414の中心を通り、開口部414の平面に対して鉛直方向に延びる中心軸に対して対称に配置されている。更に、アクチュエー

タ４０６、フィルム４０８、及びプレート４１０の中心は、開口部４１４のほぼ中心軸上に配置されている。

【０１１３】プレート４１０の中心に設けられた貫通孔４１２の面積は、アクチュエータ１０６のキャビティ１６２の開口の面積よりも大きく形成されている。アクチュエータ１０６のキャビティ１６２と貫通孔４１２とは、共にインク溜部を形成する。プレート４１０の厚さは貫通孔４１２の径に比べて小さく、例えば貫通孔４１２の径の３分の１以下の大きさに設定することが好ましい。貫通孔４１２は、モジュール体４００の中心軸に対して対称なほぼ真円の形状である。貫通孔４１２の断面の周縁はテーパー形状であっても良いステップ形状でもよい。モジュール体４００は、貫通孔４１２が容器１の内部に配置されるように容器１の底部に装着することができる。アクチュエータ１０６が垂直方向に延びるように容器１内に配置されるので、基台４０２の高さを変えてアクチュエータ１０６が容器１内部に配置される高さを変えることによりインクエンドの時点の設定を容易に変えることができる。

【０１１４】図１７は、モジュール体の更に他の実施形態を示す。図１３に示したモジュール体１００と同様に、図１７のモジュール体５００は、基台５０２および円柱部５０３を有する液体容器取付部５０１を含む。また、モジュール体５００は、リードワイヤ５０４ａ及び５０４ｂ、アクチュエータ１０６、フィルム５０８、及びプレート５１０をさらに有する。液体容器取付部５０１に含まれる基台５０２は、リードワイヤ５０４ａ及び５０４ｂを収容できるよう中心部に開口部５１４が形成され、アクチュエータ１０６、フィルム５０８、及びプレート５１０を収容できるように凹部５１３が形成される。アクチュエータ１０６はプレート５１０を介して圧電装置装着部５０５に固定される。従って、リードワイヤ５０４ａ及び５０４ｂ、アクチュエータ１０６、フィルム５０８およびプレート５１０は、液体容器取付部５０１に一体として取り付けられる。本実施形態のモジュール体５００は、平面がほぼ角丸の正方形上の基台５１０に上面が上下方向に斜めな円柱部５０３が形成されている。円柱部５０３の上面の上下方向に斜めに設けられた凹部５１３上にアクチュエータ１０６が配置されている。

【０１１５】モジュール体５００の先端は傾斜しており、その傾斜面にアクチュエータ１０６が装着されている。そのため、モジュール体５００が容器１の底部又は側部に装着されると、アクチュエータ１０６が容器１の上下方向に対して傾斜する。モジュール体５００の先端の傾斜角度は、検出性能を鑑みてほぼ３０°から６０°の間とすることが望ましい。

【０１１６】モジュール体５００は、アクチュエータ１０６が容器１内に配置されるように容器１の底部又は側部に装着される。モジュール体５００が容器１の側部に

装着される場合には、アクチュエータ１０６が、傾斜しつつ、容器１の上側、下側、又は横側を向くように容器１に取り付けられる。一方、モジュール体５００が、容器１の底部に装着される場合には、アクチュエータ１０６が、傾斜しつつ、容器１のインク供給口側を向くように容器１に取り付けられることが好ましい。

【０１１７】図１８は、図１３に示したモジュール体１００を容器１に装着したときのインク容器の底部近傍の断面図である。モジュール体１００は、容器１の側壁を貫通するように装着されている。容器１の側壁とモジュール体１００との接合面には、Ｏリング３６５が設けられ、モジュール体１００と容器１との液密を保っている。Ｏリングでシールが出来るようにモジュール体１００は図１３で説明したような円柱部を備えることが好ましい。モジュール体１００の先端が容器１の内部に挿入されることで、プレート１１０の貫通孔１１２を介して容器１内のインクがアクチュエータ１０６と接触する。アクチュエータ１０６の振動部の周囲が液体か気体かによってアクチュエータ１０６の残留振動の共振周波数が異なるので、モジュール体１００を用いてインクの消費状態を検出することができる。また、モジュール体１００に限らず、図１５に示したモジュール体４００、図１７に示したモジュール体５００、又は図１９及び図２０に示したモジュール体７００Ａ、７００Ｂ、７５０Ａ、及び７５０Ｂ、及びモールド構造体６００を容器１に装着してインクの有無を検出してもよい。

【０１１８】図１９は、モジュール体１００の更に他の実施形態を示す。図１９（Ａ）のモジュール体７５０Ａはアクチュエータ１０６と基台部３６０とを有する。モジュール体７５０Ａは前面が容器１の側壁の内面と同一面となるように、容器１に装着されている。アクチュエータ１０６は、圧電層１６０、上部電極１６４、下部電極１６６、及び振動板１７６を含む。振動板１７６の上面に下部電極１６６が形成されている。下部電極１６６の上面には圧電層１６０が形成され、圧電層１６０の上面に上部電極１６４が形成されている。したがって、圧電層１６０は、上部電極１６４及び下部電極１６６によって上下から挟まれるように形成されている。圧電層１６０、上部電極１６４、及び下部電極１６６は、圧電素子を形成する。圧電素子は振動板１７６上に形成される。圧電素子及び振動板１７６の振動領域はアクチュエータが実際に振動する振動部である。容器１の側壁には貫通孔３８５が設けられている。したがって、インクは容器１の貫通孔３８５を介して振動板１７６と接触する。

【０１１９】次に図１９（Ａ）に示したモジュール体７５０Ａの動作について説明する。上部電極１６４及び下部電極１６６は圧電層１６０に駆動信号を伝達し、圧電層１６０が検出した共振周波数の信号を記録装置に伝達する。圧電層１６０は上部電極１６４及び下部電極１６

6によって伝達された駆動信号により共振して残留振動する。この残留振動により圧電層160は逆起電力を発生する。逆起電力波形の振動周期をカウントし、その時点での共振周波数を検出することでインクの有無を検出できる。モジュール体750Aは、アクチュエータ106がアクチュエータ106の振動部の圧電素子側とは反対の面、すなわち、図19(A)では、振動板176のみが、インク容器1内のインクと接触するように容器1に装着される。図19(A)のモジュール体750Aは、図13から図17に示したリードワイヤ104a、104b、404a、404b、504a、及び504bの電極のモジュール体100への埋め込みが不要となる。そのため成形工程が簡素化される。更に、モジュール体750Aの交換が可能となりリサイクルが可能となる。また更に、アクチュエータ106は基台部360により保護されているのでアクチュエータ106を外部との接触から保護できる。

【0120】図19(B)はモジュール体750Bの更に他の実施形態を示す。図19(B)のモジュール体750Bはアクチュエータ106と基台部360とを有する。モジュール体750Bは前面が容器1の側壁の内面と同一面となるように、容器1に装着されている。アクチュエータ106は、圧電層160、上部電極164、下部電極166、及び振動板176を含む。振動板176の上面に下部電極166が形成されている。下部電極166の上面には圧電層160が形成され、圧電層160の上面に上部電極164が形成されている。したがって、圧電層160は、上部電極164及び下部電極166によって上下から挟まれるように形成されている。圧電層160、上部電極164、及び下部電極166は、圧電素子形成する。圧電素子は振動板176上に形成される。圧電素子及び振動板176の振動領域はアクチュエータが実際に振動する振動部である。容器1の側壁には薄壁部380が設けられている。モジュール体750Bは、アクチュエータ106がアクチュエータ106の振動部の圧電素子側とは反対の面、すなわち、図19(B)では、振動板176のみが、インク容器1の薄壁部380と接触するように容器1に装着される。したがって、アクチュエータ106の振動部は、薄壁部380と共に残留振動する。

【0121】次に図19(B)に示したモジュール体750Bの動作について説明する。上部電極164及び下部電極166は圧電層160に駆動信号を伝達し、圧電層160が検出した共振周波数の信号を記録装置に伝達する。圧電層160は上部電極164及び下部電極166によって伝達された駆動信号により共振して共振周期で振動する。振動板176が、容器1の薄壁部380と接触するので、アクチュエータ106の振動部は、薄壁部380と共に残留振動する。薄壁部380の容器1の内面側は、インクと接触するので、アクチュエータ106

が、薄壁部380と共に残留振動する際、この残留振動の共振周波数及び振幅は、インク残量により変化する。この残留振動により圧電層160は逆起電力を発生する。逆起電力波形の振動周期をカウントし、その時の共振周波数を検出することによりインク残量を検出することができる。

【0122】図19(B)のモジュール体750Bは、図13から図17に示したリードワイヤ104a、104b、404a、404b、504a、及び504bの電極のモジュール体100への埋め込みが不要となる。そのため成形工程が簡素化される。更に、モジュール体750Bの交換が可能となりリサイクルが可能となる。また更に、アクチュエータ106は基台部360により保護されているのでアクチュエータ106を外部との接触から保護できる。

【0123】図20(A)はモジュール体700Bを容器1に装着したときのインク容器の断面図を示す。本実施例では取付構造体の1つとしてモジュール体700Bを使用する。モジュール体700Bは、液体容器取付部360が容器1の内部に突出するようにして容器1に装着されている。取付プレート350には貫通孔370が形成され、貫通孔370とアクチュエータ106の振動部が面している。更に、モジュール体700Bの底壁には孔382が形成され、圧電装置装着部363が形成される。アクチュエータ106が孔382の一方を塞ぐようにして配備される。したがって、インクは、圧電装置装着部363の孔382及び取付プレート350の貫通孔370を介して振動板176と接触する。圧電装置装着部363の孔382及び取付プレート350の貫通孔370は、共にインク溜部を形成する。圧電装置装着部363とアクチュエータ106とは、取付プレート350及びフィルム部材によって固定されている。液体容器取付部360と容器1との接続部にはシーリング構造372が設けられている。シーリング構造372は合成樹脂等の可塑性の材料により形成されてもよいし、Oリングにより形成されてもよい。図20(A)のモジュール体700Bと容器1とは別体であるが、図20(B)のようにモジュール体700Bの圧電装置装着部を容器1の一部で構成してもよい。

【0124】図20(B)のモジュール体700Bは、図13から図17に示したリードワイヤのモジュール体への埋め込みが不要となる。そのため成形工程が簡素化される。更に、モジュール体700Bの交換が可能となりリサイクルが可能となる。

【0125】インクカートリッジが揺れる際にインクが容器1の上面あるいは側面に付着し、容器1の上面あるいは側面から垂れてきたインクがアクチュエータ106に接触することでアクチュエータ106が誤動作する可能性がある。しかし、モジュール体700Bは液体容器取付部360が容器1の内部に突出しているため、容器

1の上面や側面から垂れてきたインクによりアクチュエータ106が誤作動しない。

【0126】また、図20(A)の実施例では、振動板176と取付プレート350の一部のみが、容器1内のインクと接触するように容器1に装着される。図20(A)の実施例では、図13から図17に示したリードワイヤ104a、104b、404a、404b、504a、及び504bの電極のモジュール体への埋め込みが不要となる。そのため成形工程が簡素化される。更に、アクチュエータ106の交換が可能となりリサイクルが可能となる。

【0127】図20(B)は、アクチュエータ106を容器1に装着したときの実施例としてインク容器の断面図を示す。図20(B)の実施例によるインクカートリッジでは、保護部材361はアクチュエータ106とは別体として容器1に取り付けられている。従って、保護部材361とアクチュエータ106とはモジュールとして一体となっていないが、一方で、保護部材361はアクチュエータ106にユーザーの手が触れないように保護することができる。アクチュエータ106の前面に設けられる孔380は、容器1の側壁に配設されている。アクチュエータ106は、圧電層160、上部電極164、下部電極166、振動板176及び取付プレート350を含む。取付プレート350の上面に振動板176が形成され、振動板176の上面に下部電極166が形成されている。下部電極166の上面には圧電層160が形成され、圧電層160の上面に上部電極164が形成されている。したがって、圧電層160の主要部は、上部電極164の主要部及び下部電極166の主要部によって上下から挟まれるように形成されている。圧電層160、上部電極164、及び下部電極166のそれぞれの主要部である円形部分は、圧電素子を形成する。圧電素子は振動板176上に形成される。圧電素子及び振動板176の振動領域はアクチュエータが実際に振動する振動部である。取付プレート350には貫通孔370が設けられている。更に、容器1の側壁には孔380が形成されている。したがって、インクは、容器1の孔380及び取付プレート350の貫通孔370を介して振動板176と接触する。容器1の孔380及び取付プレート350の貫通孔370は、共にインク溜部を形成する。また、図20(B)の実施例では、アクチュエータ106は保護部材361により保護されているのでアクチュエータ106を外部との接触から保護できる。

【0128】尚、図20(A)および(B)の実施例における取付プレート350に代えて、図1の基板178を使用してもよい。

【0129】図20(C)はアクチュエータ106を含むモールド構造体600を備える実施形態を示す。本実施例では、取付構造体の1つとしてモールド構造体600を使用する。モールド構造体600はアクチュエータ

106とモールド部364とを有する。アクチュエータ106とモールド部364とは一体に成形されている。モールド部364はシリコン樹脂等の可塑性の材料によって成形される。モールド部364は内部にリードワイヤ362を有する。モールド部364はアクチュエータ106から延びる2本の足を有するように形成されている。モールド部364はモールド部364と容器1とを液密に固定するために、モールド部364の2本の足の端が半球状に形成される。モールド部364はアクチュエータ106が容器1の内部に突出するよう容器1に装着され、アクチュエータ106の振動部は容器1内のインクと接触する。モールド部364によって、アクチュエータ106の上部電極164、圧電層160、及び下部電極166はインクから保護されている。

【0130】図20(C)のモールド構造体600は、モールド部364と容器1との間にシーリング構造372が必要ないので、インクが容器1から漏れにくい。また、容器1の外部からモールド構造体600が突出しない形態であるので、アクチュエータ106を外部との接触から保護することができる。インクカートリッジが漏れる際に、インクが容器1の上面あるいは側面に付き、容器1の上面あるいは側面から垂れてきたインクが、アクチュエータ106に接触することで、アクチュエータ106が、誤作動する可能性がある。モールド構造体600は、モールド部364が、容器1の内部に突出しているので、容器1の上面や側面から垂れてきたインクにより、アクチュエータ106が誤作動しない。

【0131】図21は、図1に示したアクチュエータ106を用いたインクカートリッジ及びインクジェット記録装置の実施形態を示す。複数のインクカートリッジ180は、それぞれのインクカートリッジ180に対応した複数のインク導入部182及びホルダー184を有するインクジェット記録装置に装着される。複数のインクカートリッジ180は、それぞれ異なる種類の、例えば色のインクを収容する。複数のインクカートリッジ180のそれぞれの底面には、少なくとも音響インピーダンスを検出する手段であるアクチュエータ106が装着されている。アクチュエータ106をインクカートリッジ180に装着することによって、インクカートリッジ180内のインク残量を検出することができる。

【0132】図22は、インクジェット記録装置のヘッド部周辺の詳細を示す。インクジェット記録装置は、インク導入部182、ホルダー184、ヘッドプレート186、及びノズルプレート188を有する。インクを噴射するノズル190がノズルプレート188に複数形成されている。インク導入部182は空気供給口181とインク導入口183とを有する。空気供給口181はインクカートリッジ180に空気を供給する。インク導入口183はインクカートリッジ180からインクを導入する。インクカートリッジ180は空気導入口185と

インク供給口187とを有する。空気導入口185はインク導入部182の空気供給口181から空気を導入する。インク供給口187はインク導入部182のインク導入口183にインクを供給する。インクカートリッジ180がインク導入部182から空気を導入することによって、インクカートリッジ180からインク導入部182へのインクの供給を促す。ホルダ184は、インクカートリッジ180からインク導入部182を介して供給されたインクをヘッドプレート186に連通する。

【0133】図23は、図20に示したインクカートリッジ180の他の実施形態を示す。図23(A)のインクカートリッジ180Aは、上下方向に斜めに形成された底面194aにアクチュエータ106が装着されている。インクカートリッジ180のインク容器194の内部には、インク容器194の内部底面から所定の高さの、アクチュエータ106と直面する位置に防波壁192が設けられている。アクチュエータ106が、インク容器194の上下方向に斜めに装着されているので、インクの掛けが良好になる。

【0134】アクチュエータ106と防波壁192との間には、インクで満たされた間隙が形成される。また、防波壁192とアクチュエータ106との間隙は、毛細管力によりインクが保持されない程度に空けられている。インク容器194が横揺れしたときに、横揺れによってインク容器194内部にインクの波が発生し、その衝撃によって、気体や気泡がアクチュエータ106によって検出されてアクチュエータ106が誤動作する可能性がある。防波壁192を設けることによって、アクチュエータ106付近のインクの波を防ぎ、アクチュエータ106の誤動作を防ぐことができる。

【0135】図23(B)のインクカートリッジ180Bのアクチュエータ106は、インク容器194の供給口の側壁上に装着されている。インク供給口187の近傍であれば、アクチュエータ106は、インク容器194の側壁又は底面に装着されてもよい。また、アクチュエータ106はインク容器194の幅方向の中心に装着されることが好ましい。インクは、インク供給口187を通過して外部に供給されるので、アクチュエータ106をインク供給口187の近傍に設けることにより、インクニアエンド時点までインクとアクチュエータ106とが確実に接触する。したがって、アクチュエータ106はインクニアエンドの時点を確認に検出することができる。

【0136】更に、アクチュエータ106をインク供給口187の近傍に設けることで、インク容器をキャリッジ上のカートリッジホルダに装着する際に、インク容器上のアクチュエータ106とキャリッジ上の接点との位置決めが確実となる。その理由は、インク容器とキャリッジとの連結において最も重要なのは、インク供給口と供給針との確実な結合である。少しでもずれがあると供

給針の先端を痛めてしまったりあるいはOリングなどのシーリング構造にダメージを与えてしまいインクが漏れ出してしまからである。このような問題点を防ぐために、通常インクジェットプリンタはインク容器をキャリッジにマウントする時に正確な位置合わせができような特別な構造を有している。よって供給口近傍にアクチュエータを配置させることにより、アクチュエータの位置合わせも同時に確実なものとなるのである。さらに、アクチュエータ106をインク容器194の幅方向の中心に装着することで、より確実に位置合わせができる。インク容器が、ホルダへの装着時に幅方向中心線を中心として軸揺動した場合に、もっともその揺れが少ないからである。

【0137】図24はインクカートリッジ180の更に他の実施形態を示す。図24(A)はインクカートリッジ180Cの断面図、図24(B)は図24(A)に示したインクカートリッジ180Cの側壁194bを拡大した断面図、及び図24(C)はその正面からの透視図である。インクカートリッジ180Cは、半導体記憶手段7とアクチュエータ106とが同一の回路基板610上に形成されている。図24(B)、(C)に示すように、半導体記憶手段7は回路基板610の上方に形成され、アクチュエータ106は同一の回路基板610において半導体記憶手段7の下側に形成されている。アクチュエータ106の周囲を囲むように異型Oリング614が、側壁194bに装着される。側壁194bには、回路基板610をインク容器194に接合するためのカシメ部616が複数形成されている。カシメ部616によって回路基板610をインク容器194に接合し、異型Oリング614を回路基板610に押しつけることで、アクチュエータ106の振動領域がインクと接触することできるようにしつつ、インクカートリッジの外部と内部とを密に保つ。

【0138】半導体記憶手段7及び半導体記憶手段7付近には端子612が形成されている。端子612は半導体記憶手段7とインクジェット記憶装置等の外部との間の信号の受け渡しをする。半導体記憶手段7は、例えばEPROMなどの書き換え可能な半導体メモリによって構成されてもよい。半導体記憶手段7とアクチュエータ106とが同一の回路基板610上に形成されているので、アクチュエータ106及び半導体記憶手段7をインクカートリッジ180Cに取付ける際に1回の取付け工程で済む。また、インクカートリッジ180Cの製造時及びリサイクル時の作業工程が簡素化される。更に、部品の点数が削減されるので、インクカートリッジ180Cの製造コストが低減できる。

【0139】アクチュエータ106は、インク容器194内のインクの消費状態を検知する。半導体記憶手段7はアクチュエータ106が検出したインク残量などインクの情報格納する。すなわち、半導体記憶手段7は検

出する際に用いられるインク及びインクカートリッジの特性等の特性パラメータに関する情報を格納する。半導体記憶手段7は、予めインク容器194内のインクがフルのとき、すなわちインクがインク容器194内に満たされたとき、又はエンドのとき、すなわちインク容器194内のインクが消費されたときの共振周波数を特性パラメータの一つとして格納する。インク容器194内のインクがフル又はエンド状態の共振周波数は、インク容器が初めてインクジェット記録装置に装着されたときに格納されてもよい。また、インク容器194内のインクがフル又はエンド状態の共振周波数は、インク容器194の製造中に格納されてもよい。半導体記憶手段7に予めインク容器194内のインクがフル又はエンドのときの共振周波数を格納し、インクジェット記録装置側で共振周波数のデータを読み出すことによりインク残量を検出する際のばらつきを補正できるので、インク残量が基準値まで減少したことを正確に検出することができる。

【0140】図25は、インクカートリッジ180の更に他の実施形態を示す。図25(A)に示すインクカートリッジ180Dは、インク容器194の側壁194bに複数のアクチュエータ106を装着する。図5に示した、一体成形された複数のアクチュエータ106を、これら複数のアクチュエータ106として用いることが好ましい。複数のアクチュエータ106は、上下方向に間隔をおいて側壁194bに配置されている。複数のアクチュエータ106を上下方向に間隔をおいて側壁194bに配置することによって、インク残量を段階的に検出することができる。

【0141】図25(B)に示すインクカートリッジ180Eは、インク容器194の側壁194bに上下方向に長いアクチュエータ606を装着する。上下方向に長いアクチュエータ606によって、インク容器194内のインク残量の変化を連続的に検出することができる。アクチュエータ606の長さは、側壁194bに高さの半分以上の長さを有することが望ましく、図25(B)においては、アクチュエータ606は側壁194bのほぼ上端からほぼ下端までの長さを有する。

【0142】図25(C)に示すインクカートリッジ180Fは、図25(A)に示したインクカートリッジ180Dと同様に、インク容器194の側壁194bに複数のアクチュエータ106を装着し、複数のアクチュエータ106の直面に所定の間隔をおいて上下方向に長い防波壁192を備える。図5に示した、一体成形された複数のアクチュエータ106を、これら複数のアクチュエータ106として用いることが好ましい。アクチュエータ106と防波壁192との間には、インクで満たされた間隙が形成される。また、防波壁192とアクチュエータ106との間隔は、毛細管力によりインクが保持されない程度に空けられている。インク容器194が横揺れしたときに横揺れによってインク容器194内部に

インクの波が発生し、その衝撃によって気体や気泡がアクチュエータ106によって検出されてしまい、アクチュエータ106が誤作動する可能性がある。本発明のように防波壁192を設けることによって、アクチュエータ106付近のインクの波立ちを防ぎ、アクチュエータ106の誤作動を防ぐことができる。また、防波壁192はインクが揺動することによって発生した気泡がアクチュエータ106に侵入するのを防ぐ。

【0143】図26は、インクカートリッジ180Gの更に他の実施形態を示す。図26(A)のインクカートリッジ180Gは、インク容器194の上面194cから下方に延びる複数の隔壁212を有する。それぞれの隔壁212の下端とインク容器194の底面とは所定の間隔が空けられているので、インク容器194の底部は連通している。インクカートリッジ180Gは複数の隔壁212のそれぞれによって区画された複数の収容室213を有する。複数の収容室213の底部は互いに連通する。複数の収容室213のそれぞれにおいて、インク容器194の上面194cにはアクチュエータ106が装着されている。図5に示した、一体成形されたアクチュエータ106を、これら複数のアクチュエータ106として用いることが好ましい。アクチュエータ106は、インク容器194の収容室213の上面194cのほぼ中央に配置される。収容室213の容量はインク供給口187側が最も大きく、インク供給口187からインク容器194の奥へ遠ざかるにつれて、収容室213の容量が徐々に小さくなっていく。したがって、アクチュエータ106が配置される間隔はインク供給口187側が広く、インク供給口187からインク容器194の奥へと遠ざかるにつれ、狭くなっていく。

【0144】インクは、インク供給口187から排出され、空気が空気導入口185から入るの、インク供給口187側の収容室213からインクカートリッジ180Gの奥の方の収容室213へとインクが消費される。例えば、インク供給口187に最も近い収容室213のインクが消費されて、インク供給口187に最も近い収容室213のインクの水位が下がっている間、他の収容室213にはインクが満たされている。インク供給口187に最も近い収容室213のインクが消費され尽くすと、空気が、インク供給口187から数えて2番目の収容室213に侵入し、2番目の収容室213内のインクが消費され始めて、2番目の収容室213のインクの水位が下がりはじめ、この時点で、インク供給口187から数えて3番目以降の収容室213には、インクが満たされている。このように、インク供給口187に近い収容室213から遠い収容室213へと順番にインクが消費される。

【0145】このように、アクチュエータ106がそれぞれの収容室213ごとにインク容器194の上面194cに間隔をおいて配置されているので、アクチュエー

タ１０６はインク量の減少を段階的に検出することができ、更に、収容室２１３の容量が、インク供給口１８７から収容室２１３の奥へと徐々に小さくなっているため、アクチュエータ１０６が、インク量の減少を検出する時間間隔が徐々に小さくなり、インクエンドに近づくほど頻度を高く検出することができる。

【０１４６】図２６（Ｂ）のインクカートリッジ１８０Ｈは、インク容器１９４の上面１９４ｃから下方に延びる一つの隔壁２１２を有する。隔壁２１２の下端とインク容器１９４の底面とは所定の間隔が空けられているので、インク容器１９４の底面は連通している。インクカートリッジ１８０Ｈは隔壁２１２によって区画された２室の収容室２１３ａ及び２１３ｂを有する。収容室２１３ａ及び２１３ｂの底面は互いに連通する。インク供給口１８７個の収容室２１３ａの容量はインク供給口１８７から見て奥の方の収容室２１３ｂの容量より大きい。収容室２１３ｂの容量は、収容室２１３ａの容量の半分以上より小さいことが好ましい。

【０１４７】収容室２１３ｂの上面１９４ｃにアクチュエータ１０６が装着される。更に、収容室２１３ｂには、インクカートリッジ１８０Ｈの製造時に入る気泡を捕らえる溝であるバッファ２１４が形成される。図２６（Ｂ）において、バッファ２１４は、インク容器１９４の側壁１９４ｂから上方に延びる溝として形成される。バッファ２１４はインク収容室２１３ｂ内に侵入した気泡を捕らえるので、気泡によってアクチュエータ１０６がインクエンドと検出する誤動作を防止することができる。また、アクチュエータ１０６を収容室２１３ｂの上面１９４ｃに設けることにより、インクニアエンドが検出されてから完全にインクエンド状態になるまでのインク量に対して、ドットカウンタによって把握した収容室２１３ａでのインクの消費状態に対応した補正をかけることで、最後までインクを消費することができる。更に、収容室２１３ｂの容量を隔壁２１２の長さや間隔を変えたりすることなどによって調節することにより、インクニアエンド検出後の消費可能インク量を変えることができる。

【０１４８】図２６（Ｃ）は、図２６（Ｂ）のインクカートリッジ１８０Ｉの収容室２１３ｂに多孔質部材２１６が充填されている。多孔質部材２１６は、収容室２１３ｂ内の上面から下面までの全空間を埋めるように設置される。多孔質部材２１６は、アクチュエータ１０６と接触する。インク容器が倒れたときや、キャリッジ上での往復運動中に空気はインク収容室２１３ｂ内に侵入してしまい、これがアクチュエータ１０６の誤動作を引き起こす可能性がある。しかし、多孔質部材２１６が備えられていると、空気を捕らえてアクチュエータ１０６に空気が入るのを防ぐことができる。また、多孔質部材２１６はインクを保持するのでインク容器が傾斜することにより、インクがアクチュエータ１０６にかかってアクチ

ュエータ１０６がインク無しをインク有りとして誤検出するのを防ぐことができる。多孔質部材２１６は最も容量が小さい収容室２１３に設置することが好ましい。また、アクチュエータ１０６を収容室２１３ｂの上面１９４ｃに設けることにより、インクニアエンドが検出されてから完全にインクエンド状態になるまでのインク量に補正をかけ、最後までインクを消費することができる。更に、収容室２１３ｂの容量を隔壁２１２の長さや間隔を変えたりすることなどによって調節することにより、インクニアエンド検出後の消費可能インク量を変えることができる。

【０１４９】図２６（Ｄ）は、図２６（Ｃ）のインクカートリッジ１８０Ｊの多孔質部材２１６が孔径の異なる２種類の多孔質部材２１６Ａ及び２１６Ｂによって構成されているインクカートリッジ１８０Ｊを示す。多孔質部材２１６Ａは、多孔質部材２１６Ｂの上方に配置されている。上側の多孔質部材２１６Ａの孔径は、下側の多孔質部材２１６Ｂの孔径より大きい。もしくは、多孔質部材２１６Ａは、多孔質部材２１６Ｂよりも液体透過性が低い部材で形成される。孔径の小さい多孔質部材２１６Ｂの方が孔径の大きい多孔質部材２１６Ａより毛細管力は大きいので、収容室２１３ｂ内のインクが下側の多孔質部材２１６Ｂに集まり、保持される。したがって、一度空気がアクチュエータ１０６まで到達してインク無しを検出すると、インクが再度アクチュエータに到達してインク有りとして検出することが無い。更に、アクチュエータ１０６から近い側の多孔質部材２１６Ｂにインクが吸収されることで、アクチュエータ１０６近傍のインクの濃度が良くなり、インク有無を検出するときの音響インピーダンス変化の変化量が大きくなる。また、アクチュエータ１０６を収容室２１３ｂの上面１９４ｃに設けることにより、インクニアエンドが検出されてから完全にインクエンド状態になるまでのインク量に補正をかけ、最後までインクを消費することができる。更に、収容室２１３ｂの容量を隔壁２１２の長さや間隔を変えたりすることなどによって調節することにより、インクニアエンド検出後の消費可能インク量を変えることができる。

【０１５０】図２７は、図２６（Ｃ）に示したインクカートリッジ１８０Ｋの他の実施形態であるインクカートリッジ１８０Ｋを示す断面図である。図２７に示すインクカートリッジ１８０の多孔質部材２１６は、多孔質部材２１６の下部の水平方向の断面積が、インク容器１９４の底面の方向にむけて徐々に小さくなるように圧縮され、孔径が小さくなるよう設計されている。図２７

（Ａ）のインクカートリッジ１８０Ｋは、多孔質部材２１６の下の方の孔径が小さくなるように圧縮するために側壁にリブが設けられている。多孔質部材２１６下部の孔径は圧縮されることにより、小さくなっているため、インクは多孔質部材２１６下部へと集められ、保持され

る。アクチュエータ106から遠い側の多孔質部材216下部にインクが吸収されることで、アクチュエータ106近傍のインクの捌けが良くなり、インク有無を検出するときの音響インピーダンス変化の変化量が大きくなる。したがって、インクが揺れることによってインカートリッジ180K上面に装着されたアクチュエータ106にインクがかかっているし、アクチュエータ106が、インク無しをインク有りと誤検出することを防止することができる。

【0151】一方、図27(B)及び図27(C)のインカートリッジ180Lは、多孔質部材216の下部の水平方向の断面積が、インク容器194の幅方向において、インク容器194の底面にむけて徐々に小さくなるよう圧縮するために、収容室の水平方向の断面積がインク容器194の底面の方向にむけて徐々に小さくなる。多孔質部材216下部の孔径は圧縮されることにより、小さくなっているため、インクは多孔質部材216の下部へと集められ、保持される。アクチュエータ106から遠い側の多孔質部材216Bの下部にインクが吸収されることで、アクチュエータ106近傍のインクの捌けが良くなり、インク有無を検出するときの音響インピーダンス変化の変化量が大きくなる。したがって、インクが揺れることによって、インカートリッジ180Lの上面に装着されたアクチュエータ106にインクがかかっているし、アクチュエータ106が、インク無しをインク有りと誤検出することを防止することができる。

【0152】図28は、アクチュエータ106を用いたインカートリッジの更なる実施形態を示す。図28(A)のインカートリッジ220Aは、インカートリッジ220Aの上面から下方へと延びるように設けられた第1の隔壁222を有する。第1の隔壁222の下端とインカートリッジ220Aの底面との間には所定の間隔が空けられているので、インクは、インカートリッジ220Aの底面を通じてインク供給口230へ流入できる。第1の隔壁222よりインク供給口230側には、インカートリッジ220Aの底面より上方に延びるように第2の隔壁224が、形成されている。第2の隔壁224の上端とインカートリッジ220A上面との間には所定の間隔が空けられているので、インクは、インカートリッジ220Aの上面を通じてインク供給口230へ流入できる。

【0153】第1の隔壁222によって、インク供給口230から見て、第2の隔壁222の奥の方に第1の収容室225aが形成される。一方、第2の隔壁224によって、インク供給口230から見て第2の隔壁224の手前側に第2の収容室225bが形成される。第1の収容室225aの容量は、第2の収容室225bの容量より大きい。第1の隔壁222及び第2の隔壁224の間、毛管現象を起こせるだけの間隔が空けられること

により、毛管路227が形成される。したがって、第1の収容室225aのインクは、毛管路227の毛細管能力により、毛管路227に集められる。そのため、気体や気泡が第2の収容室225bへ混入するのを防止することができる。また、第2の収容室225b内のインクの水位は、安定的に徐々に下降できる。インク供給口230から見て、第1の収容室225aは、第2の収容室225bより奥に形成されているので、第1の収容室225aのインクが消費された後、第2の収容室225bのインクが消費される。

【0154】インカートリッジ220Aのインク供給口230側の側壁、すなわち第2の収容室225bのインク供給口230側の側壁には、アクチュエータ106が装着されている。アクチュエータ106は、第2の収容室225b内のインクの消費状態を検知する。アクチュエータ106を、第2の収容室225bの側壁に装着することによって、インクエンドにより近い時点でのインク残量を安定的に検出することができる。更に、アクチュエータ106を第2の収容室225bの側壁に装着する高さを変えることにより、どの時点でのインク残量をインクエンドにするかを、自由に設定することができる。毛管路227によって第1の収容室225aから第2の収容室225bへインクが供給されることにより、アクチュエータ106は、インカートリッジ220Aの横揺れによるインクの横揺れの影響を受けないので、アクチュエータ106は、インク残量を確実に測定できる。更に、毛管路227が、インクを保持するので、インクが第2の収容室225bから第1の収容室225aへ逆流するのを防ぐ。

【0155】インカートリッジ220Aの上面には、逆止弁228が設けられている。逆止弁228によって、インカートリッジ220Aが横揺れしたときに、インクがインカートリッジ220A外部に漏れるのを防ぐことができる。更に、逆止弁228をインカートリッジ220Aの上面に設置することで、インクのインカートリッジ220Aからの蒸発を防ぐことができる。インカートリッジ220A内のインクが消費されて、インカートリッジ220A内の負圧が逆止弁228の圧力を越えると、逆止弁228が開いて、インカートリッジ220Aに空気を吸入し、その後閉じてインカートリッジ220A内の圧力を一定に保持する。

【0156】図28(C)及び(D)は、逆止弁228の詳細の断面を示す。図28(C)の逆止弁228は、ゴムにより形成された羽根232aを有する弁232を有する。インカートリッジ220の外部との通気孔233が、羽根232aに対向してインカートリッジ220に設けられる。羽根232aによって、通気孔233が、開閉される。逆止弁228は、インカートリッジ220内のインクが減少し、インカートリッジ220内の負圧が逆止弁228の圧力を越えると、羽根23

2 a が、インクカートリッジ 2 2 0 の内側に開き、外部の空気をインクカートリッジ 2 2 0 内に取り入れる。図 2 8 (D) の逆止弁 2 2 8 は、ゴムにより形成された弁 2 3 2 とパネ 2 3 5 とを有する。逆止弁 2 2 8 は、インクカートリッジ 2 2 0 内の負圧が逆止弁 2 2 8 の圧力を越えたと、弁 2 3 2 が、パネ 2 3 5 を押圧して開き、外部の空気をインクカートリッジ 2 2 0 内に吸入し、その後閉じてインクカートリッジ 2 2 0 内の負圧を一定に保持する。

【0157】図 2 8 (B) のインクカートリッジ 2 2 0 B は、図 2 8 (A) のインクカートリッジ 2 2 0 A において逆止弁 2 2 8 を設ける代わりに第 1 の収容室 2 2 5 a に多孔質部材 2 4 2 を配置している。多孔質部材 2 4 2 は、インクカートリッジ 2 2 0 B 内のインクを保持すると共に、インクカートリッジ 2 2 0 B が横揺れしたときに、インクがインクカートリッジ 2 2 0 B の外部へ漏れるを防ぐ。

【0158】以上、キャリッジに装着される、キャリッジは別体のインクカートリッジにおいて、インクカートリッジ又はキャリッジにアクチュエータ 1 0 6 を装着する場合について述べたが、キャリッジと一体化され、キャリッジと共に、インクジェット記録装置に装着されるインクタンクにアクチュエータ 1 0 6 を装着してもよい。更に、キャリッジとインク容器とが一体となって、キャリッジにインクを供給するオフキャリッジ方式のインクタンクにアクチュエータ 1 0 6 を装着してもよい。またさらに、記録ヘッドとインク容器とが一体となって交換可能に構成されたインクカートリッジに、本発明のアクチュエータを装着してもよい。

【0159】以上、本発明を実施の形態を用いて説明したが、本発明の技術的範囲は上記実施の形態に記載の範囲には限定されない。上記実施の形態に、多様な変更又は改良を加えることができる。その様な変更又は改良を加えた形態も本発明の技術的範囲に含まれることが、特許請求の範囲の記載から明らかである。

【0160】

【発明の効果】本発明の圧電装置、モジュール体、液体容器、及びインクカートリッジは、液体の残量を正確に検出でき、かつ複雑なシール構造が不要である。更に、本発明の圧電装置、モジュール体、液体容器、及びインクカートリッジは、安価に製造でき、液体容器への実装性もよい。

【図面の簡単な説明】

【図 1】アクチュエータ 1 0 6 の詳細を示す図である。

【図 2】アクチュエータ 1 0 6 の周辺およびその等価回路を示す図である。

【図 3】インクの密度とアクチュエータ 1 0 6 によって検出されるインクの共振周波数との関係を示す図である。

【図 4】アクチュエータ 1 0 6 の逆起電力波形を示す図

である。

【図 5】アクチュエータ 1 0 6 の他の実施形態を示す図である。

【図 6】図 5 に示したアクチュエータ 1 0 6 の一部分の断面を示す図である。

【図 7】図 6 に示したアクチュエータ 1 0 6 の全体の断面を示す図である。

【図 8】図 5 に示したアクチュエータ 1 0 6 の製造方法を示す図である。

【図 9】本発明のインクカートリッジの更に他の実施形態を示す図である。

【図 10】貫通孔 1 c の他の実施形態を示す図である。

【図 11】アクチュエータ 6 6 0 の他の実施形態を示す図である。

【図 12】アクチュエータ 6 7 0 の更に他の実施形態を示す図である。

【図 13】モジュール体 1 0 0 を示す斜視図である。

【図 14】図 13 に示したモジュール体 1 0 0 の構成を示す分解図である。

【図 15】モジュール体 1 0 0 の他の実施形態を示す図である。

【図 16】図 15 に示したモジュール体 1 0 0 の構成を示す分解図である。

【図 17】モジュール体 1 0 0 の更に他の実施形態を示す図である。

【図 18】図 13 に示したモジュール体 1 0 0 をインク容器 1 に装着した断面の例を示す図である。

【図 19】モジュール体 1 0 0 の更に他の実施形態を示す図である。

【図 20】モジュール体 1 0 0 の更に他の実施形態を示す図である。

【図 21】図 1 および図 2 に示したアクチュエータ 1 0 6 を用いたインクカートリッジ及びインクジェット記録装置の実施形態を示す図である。

【図 22】インクジェット記録装置の詳細を示す図である。

【図 23】図 22 に示したインクカートリッジ 1 8 0 の他の実施形態を示す図である。

【図 24】インクカートリッジ 1 8 0 の更に他の実施形態を示す図である。

【図 25】インクカートリッジ 1 8 0 の更に他の実施形態を示す図である。

【図 26】インクカートリッジ 1 8 0 の更に他の実施形態を示す図である。

【図 27】図 26 (C) に示したインクカートリッジ 1 8 0 の他の実施形態を示す図である。

【図 28】モジュール体 1 0 0 を用いたインクカートリッジの更に他の実施形態を示す図である。

【符号の説明】

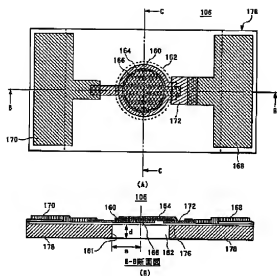
1・・・容器

1 a・・・底面	1 9 4 b・・・側壁
1 b・・・側壁	1 9 4 c・・・上面
1 c、9 4 0 a・・・貫通孔	2 1 2・・・隔壁
1 d・・・側面	2 1 3、2 1 3 a、2 1 3 b・・・収容室
1 e、1 f・・・段差部	2 1 4・・・バンプア
1 g、1 h・・・溝	2 1 6、2 1 6 a、2 1 6 b・・・多孔質部材
2・・・インク供給口	2 2 0・・・インクカートリッジ
6 7・・・板材	2 2 2・・・第1の隔壁
6 8・・・フロート	2 2 4・・・第2の隔壁
7 1・・・接着剤層	2 2 5 a・・・第1の収容室
7 8、8 0、1 7 8・・・基板	2 2 5 b・・・第2の収容室
7 3、8 2、圧電振動板	2 2 7・・・毛管路
7 4、7 5・・・インク吸収体	2 2 8・・・逆弁
7 6・・・パッキン	2 3 0・・・インク供給口
7 7・・・カシメ孔	2 3 2・・・弁
8 1・・・凹部	2 3 2 a・・・羽根
1 0 0、4 0 0、5 0 0、7 0 0・・・モジュール体	2 3 3・・・通気孔
1 0 1、4 0 1、5 0 1・・・液体容器取付部	2 3 5・・・パネ
1 0 2・・・基台	2 4 2・・・多孔質部材
1 0 4、3 6 2・・・リードワイヤ	2 5 0・・・キャリッジ
1 0 5、4 0 5、5 0 5・・・圧電装置装着部	2 5 2・・・記録ヘッド
1 0 6、6 5 0、6 6 0、6 7 0・・・アクチュエータ	2 5 4・・・インク供給針
1 0 8・・・フィルム	2 5 6・・・サブタンクユニット
1 1 0・・・プレート	2 5 8、2 5 8'・・・凸部
1 1 2、4 1 2、3 7 0・・・貫通孔	2 6 0、2 6 0'・・・弾性波発生手段
1 1 3・・・凹部	2 6 2・・・インク室
1 1 4・・・開口部	2 6 6・・・膜弁
1 1 6・・・円柱部	2 7 0・・・弁体
1 6 0・・・圧電層	2 7 2・・・インクカートリッジ
1 6 2・・・キャピティ	2 7 4・・・容器
1 6 4・・・上部電極	2 7 4 a・・・底面
1 6 6・・・下部電極	2 7 4 b・・・側面
1 6 8・・・上部電極端子	2 7 6・・・インク供給口
1 7 0・・・下部電極端子	2 7 8・・・凹部
1 7 2・・・補助電極	2 8 0、2 8 0'・・・ゲル化材
1 7 4・・・圧電素子	2 8 2・・・パッキン
1 7 6・・・振動板	2 8 4・・・パネ
1 8 0・・・インクカートリッジ	2 8 6・・・弁体
1 8 1・・・空気供給口	2 8 8・・・半導体記憶手段
1 8 2・・・インク導入部	2 9 0・・・容器
1 8 3・・・インク導入口	2 9 0 a・・・底面
1 8 4・・・ホルダー	2 9 2、2 9 4、2 9 6・・・インク室
1 8 5・・・空気導入口	2 9 8、3 0 0、3 0 2・・・インク供給口
1 8 6・・・ヘッドプレート	3 0 4、3 0 6、3 0 8・・・ゲル化材
1 8 7・・・インク供給口	3 1 0、3 1 2、3 1 4・・・凹部
1 8 8・・・ノズルプレート	3 1 6・・・板材
1 9 0・・・ノズル	3 1 8・・・フロート
1 9 2・・・防波壁	3 5 0・・・取付プレート
1 9 4・・・インク容器	3 6 0・・・液体容器取付部
1 9 4 a・・・底面	3 6 4・・・モールド部

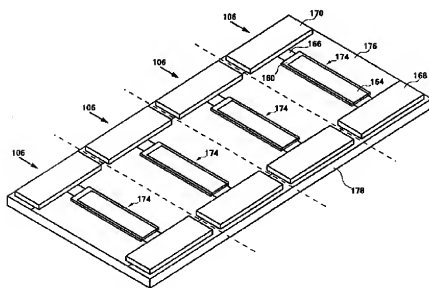
372・・・シーリング構造
 402、502・・・基台
 403、503・・・円柱部
 404、504・・・リードワイヤ
 408、508・・・フィルム
 410、510・・・プレート
 413、513・・・凹部
 414、514・・・開口部
 600・・・モールド構造体

606・・・アクチュエータ
 610・・・回路基板
 612・・・端子
 940、941・・・グリーンシート
 942、944・・・導電層
 944'・・・接続部
 947、948・・・スペーサ部材
 Δh1、Δh2・・・液面の変化
 K・・・インク

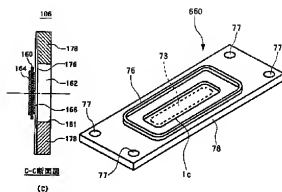
【図1】



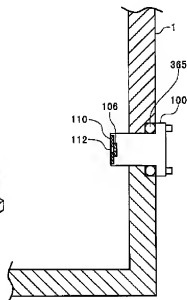
【図5】



【図11】

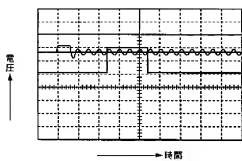


【図18】

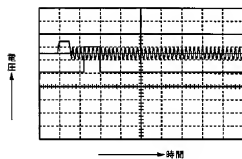


【図 4】

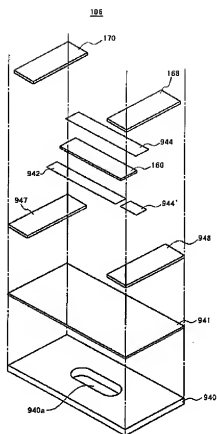
(A)



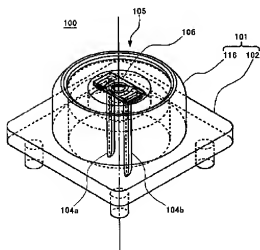
(B)



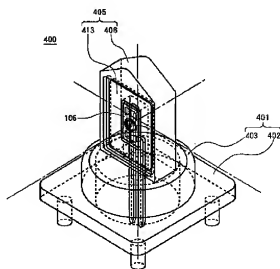
【図 8】



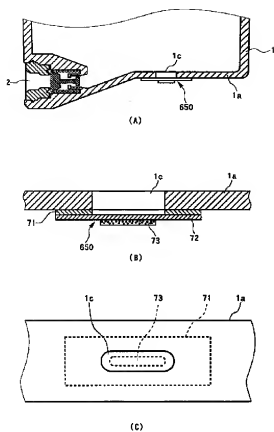
【図 13】



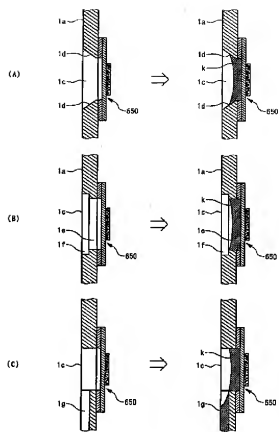
【図 15】



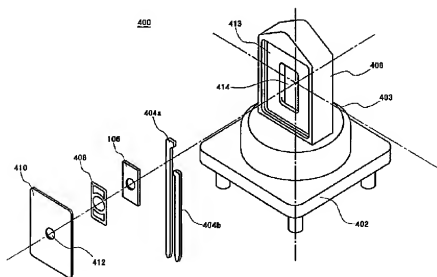
【図 9】



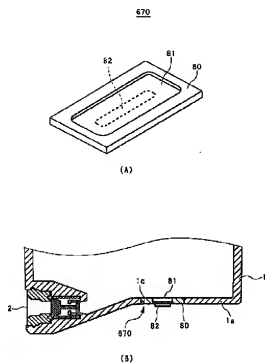
【図 10】



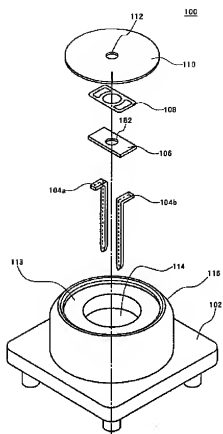
【図 16】



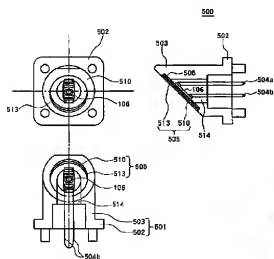
【图 12】



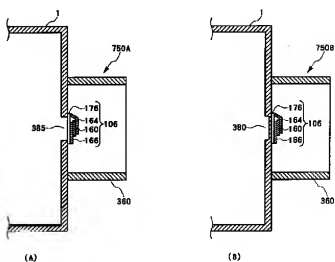
【图 14】



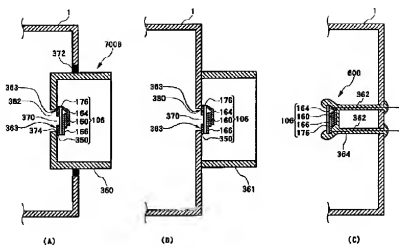
【图 17】



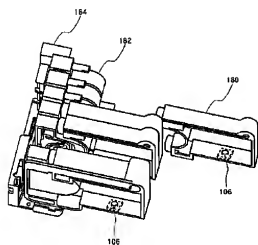
【图 19】



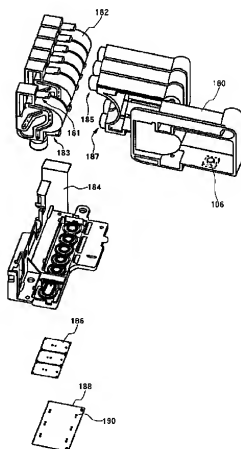
【図 20】



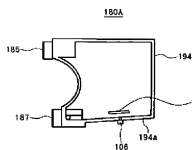
【図 21】



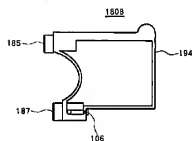
【図 22】



【図 23】

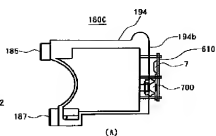


(A)

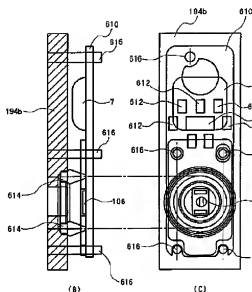


(B)

【図 24】



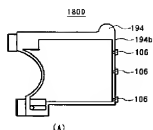
(A)



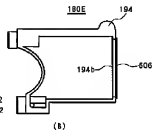
(B)

(C)

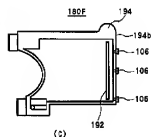
【図 25】



(A)

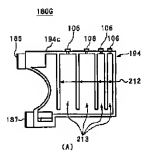


(B)

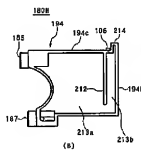


(C)

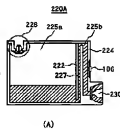
【図 26】



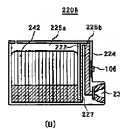
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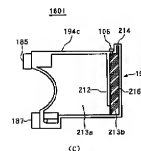
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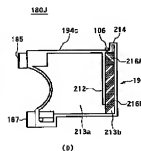
(A)



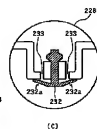
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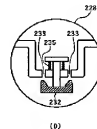
(C)



(D)



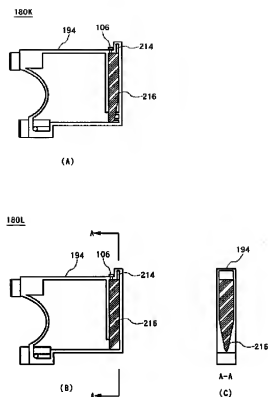
(C)



(D)

【図 28】

【図 27】



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